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1998

An Examination of the Effect of Incentives on the Cost, Schedule and Safety Performance of Construction Contracts

by

James David Oliver, B.S.

Thesis

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Acknowledgements

As I reflect on the result of a year's study, I feel a sense of accomplishment in this project. My goal has been to substantiate the use of incentives in construction contracting. At this time I would like to acknowledge many people and organizations that have made this endeavor possible:

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August 1998

Abstract

An Examination of the Effect of Incentives on the Cost, Schedule and Safety Performance of Construction Contracts

by

James David Oliver, M.S.E.
The University of Texas at Austin, 1998
Supervisor: John D. Borcherding

The research conducted in this report consists of an in depth examination of the effect of incentives on the cost, schedule and safety of construction contracts. The data for this study was obtained from two surveys conducted by the Construction Industry Institute in 1997 and 1998. This data-base includes over 400 projects from 100 different companies. Projects are examined based on cost, schedule and safety factors which are calculated and than compared for projects with positive incentives, negative incentives, both positive and negative incentives and no incentives.

Table of Contents

List of Tables viii

List of Figures ix

Chapter 1 1

Introduction 1

- Motivation 1
- Objectives 1

Chapter 2 5

Literature Review/Previous Research 5

- Background 5
- History of Incentive Contracting 6
- Construction Contracts 8
- Types of Construction Contracts 10
- Types of Incentives 14
  - Negative Incentives/Liquidated Damages 14
  - Positive Incentives/Bonus Incentives 16
- Incentive Fee Calculation 18
- Incentive Fee Goals 22
- Previous Research Results 24

Chapter 3 26

Data Gathering by the Construction Industry Institute 26

- First CII Survey 26
- Second CII Survey 30

Chapter 4 33

Analysis Methodology 33

Background 33

First Survey Questions 34

Second Survey Questions 34

Analysis Plan 35

Chapter 5 38

Analysis of Data 38

Projects with Incentives 38

Calculation of Factors 41

Cost Incentive Analysis 42

Schedule Incentives 49

Safety Incentives 55

Chapter 6 61

Conclusions 61

The First Hypothesis 61

The Second Hypothesis 63

The Third Hypothesis 64

Appendix A: Analysis of Data by Owner or Contractor, and by First or Second Survey for Factors 66

Bibliography 79

Vita 81

List of Tables

Table III - 1, Summary of Project Distribution, First Survey 27

Table III - 2, Summary of Project Distribution, Second Survey 30

Table V - 1, Projects with Construction Phase Incentives 40

Table V - 2, Factors Calculated for Projects with Cost Incentives 43

Table V - 3, Factors Calculated for Projects with Schedule Incentives 50

Table V - 4, Factors Calculated for Projects with Safety Incentives 56

Table VI - 1, Summary of the Effects of Incentives on Construction 62

List of Figures

Figure II -1, Fixed Price Incentive Contract Fee Graph.. 21

Figure II - 2, Cost Plus Incentive Contract Fee Graph.. 22

Figure III - 1, Contractor Functions, First Survey.. 28

Figure III - 2, Distribution of Project Cost, First Survey 28

Figure III - 3, Nature of Projects, First Survey 29

Figure III - 4, Contractors Functions, Second Survey.. 31

Figure III -5, Distribution of Project Cost, Second Survey.................................. 31

Figure III - 6, Nature of the Projects, Second Survey.. 32

Figure V - 1, Histogram, Cost Incentives Effect on Budget Factor...................... 44

Figure V - 2, Histogram, Cost Incentives Effect on Cost Growth Factor............. 46

Figure V - 3, Effect of Cost Incentives on Budget and Cost Growth Factors....... 47

Figure V - 4, Histogram, Schedule Incentives Effect on Schedule Factor 51

Figure V - 5, Histogram, Schedule Incentives Effect on Schedule Growth 52

Figure V - 6, Effect of Schedule Incentives on Schedule and Schedule Growth.. 53

Figure V - 7, Histogram, Effect of Safety Incentives on RIR.............................. 57

Figure V - 8, Histogram, Effect of Safety Incentives on LWCIR......................... 58

Figure V - 9, Effect of Safety Incentives on RIR and LWCIR............................. 59

Chapter 1

Introduction

MOTIVATION

This thesis is an attempt to quantify the benefits or lack of benefits that incentives introduce into the area of construction contracting. Historically the owner of a project will use incentives in order to promote attention and efficiency to an entire project or to a particular aspect of a project.

The types of incentives fall into two primary categories, negative and positive incentives. The negative incentive is often categorized by some form of penalty that is applied to the contract for failure to meet specified goals. This form of incentive is commonly used in those situations where enforcement of the contract completion date is of particular importance. In these situations the contract will employ a liquidated damages clause as typically seen in fixed price contracts. Conversely, positive incentives offer some form of consideration for exceeding specified goals. The use of this type of incentive to control costs in a cost reimbursable-type contract is common throughout construction contracting.

OBJECTIVES

This report will analyze the effect of incentives on project data collected by the Construction Industry Institute (CII). Projects with and without incentives will be compared based on cost, schedule and safety performance.

An initial assumption of the effect of negative incentives is necessary to begin the investigation. It can be theorized that negative incentives would produce an awareness of certain contract goals and thus would encourage contractors to meet whatever minimum requirement is necessary to ensure that no negative impact is realized. Consequently, the principal motivation of the contractor is not to improve upon the contractual requirements. Rather the contractor's motivation is simply meeting the minimum requirements that are commonly set at normal industry standards. Because an owner must provide realistic goals to avoid accusations of "Impossibility of Performance" and henceforth costly legal battles, minimum requirements can not be expected to be overly rigid. Therefore, only a minimum improvement over the normal industry standards may be specified. As a result, the potential improvement that can be specified by the owner is limited. On these assumptions, the first hypothesis that will be proposed is "Projects with negative incentives have slightly better cost, schedule, and safety performance then projects with no incentives."

A hypothesis about the effect of positive incentives must also be developed. A positive incentive is based on a minimum standard with some type of additional consideration for significant improvement upon that minimum standard. In such a scenario an owner is able to specify that the minimum standard be set at normal industry expectations. Likewise an owner can then expect that the contractor will be motivated to improve upon this standard by using innovation and ingenuity in order to achieve the incentive and maximize profit. In this case the owner avoids the potential liability of lawsuits while still

achieving above average results. Based on these assumptions, it can be expected that the motivation to exceed the minimum requirement is greater than that of negative incentives. Consequently, the second hypothesis proposed is "Projects with positive incentives have better cost, schedule and safety performance than projects with no incentives or projects with only negative incentives."

The use of incentives where both positive and negative incentives are used in a contract is not unusual. A hypothesis about the effect of both positive and negative incentives must also be developed. Theorizing from previous assumptions used to propose the first two hypothesis leads to the third hypothesis, namely that "Projects with both positive and negative incentives have much better cost, schedule and safety performance than projects with no incentives or projects with only positive or negative incentives."

The use of incentives for multiple purposes, namely the use of cost, schedule and safety incentives on the same project also occurs. However, an analysis of contracts that use incentives for multiple purposes can provide inaccurate or skewed results. A contractor, in attempting to achieve one incentive can negatively impact on other incentives. An example of this is a contract that is heavily loaded with schedule incentives but also has safety incentives. To illustrate, to meet the schedule incentives and maximize profit, the contractor undertakes working overtime and long workweeks. This type of scheduling could easily produce results that show that the safety incentives produced no benefit or actually produced a negative benefit. Thus results from these mixed incentive contracts must be examined closely and in context with other factors related to the

project. This study will make no attempt to analyze these mixed incentive contracts. Only an examination of the effect of incentives on the primary purpose will be done. For example, cost incentives will be examined solely on their effect on the cost performance of the project. This methodology of analysis will also be applied to schedule and safety incentives.

Chapter 2

Literature Review/Previous Research

BACKGROUND

In this chapter, a review of significant literature and previous research related to the principles, foundation and use of incentives in construction contracting is presented. Given that literature discussing incentives in construction contracts is not abundant, this chapter provides background information that assists in understanding the subject of incentives by linking together major concepts.

Construction project data such as that gathered by CII has not been available before this time. The difficulty in obtaining financial data due to concerns from contractors regarding competitive advantages has been the primary stumbling block. The CII data used in this study includes over 400 projects obtained from approximately 100 companies. Because of the potential negative impact the results of this study could have upon the competitive capability of the companies involved, no company names or company comparisons have been used in this analysis.

Most discussion of incentives revolves around the issue of how to use incentives with an accepted premise that incentives are effective. This then leads to the question of whether incentives are effective, and if so, whether benefits can

be quantified. And finally, what types of incentives are best? These are some of the issues that will be the focus of this analysis.

Previous attempts to analyze incentives have been based on a total cost evaluation of the contract with little attention given to specific factors that describe the "health" of a construction contract. A contract can superficially appear to be successful in that it meets an incentive clause, yet suffer serious deficiencies in other areas. A look at factors that describe cost growth or project safety may show that even though the contractor was successful in meeting a schedule incentive, the overall project suffered in other key areas.

HISTORY OF INCENTIVE CONTRACTING

The history of incentives in construction contracts most likely started in the Stone Age. Some ambitious Neanderthal probably contracted to build a primitive dwelling with a scheduled completion date before the first winter storm. The incentive being that he would get a knock on the head (from his mate, no less!) if he failed to complete the contract by the proscribed event.

In all seriousness, the incentive contract has been around in some form or another for a long time. The military used an incentive contract with the Wright Brothers to construct the first military airplane in 1908. This performance incentive included a provision for a target speed of 40 mph with a target price of $25,000. Also included in the contract was a provision calling for a sliding scale of payments based on the actual airspeed of the plane. This contract had a very

steep incentive price of $15,000 if the minimum airspeed of 36 mph was obtained and a price of $35,000 for the maximum airspeed of 44 mph.[1]

While the contract entered in between the Wright Brothers and the military shows that incentive contracts are not a recent phenomenon, incentive contract use increased after World War II.

The employment of incentive contracts on a formalized basis can be found in the aircraft industry after World War II. After the war the incentive contract became the practice in follow-on production situations where the dollar value of contracts was large, the configuration of the aircraft was constantly changing and companies were often financially incapable of taking large risks. In this situation work was normally begun on a letter contract or a delayed target incentive contract with the target price being established after a substantial amount of work under the contract had been completed. In this industry, the contractors had cost accounting systems where lot costs were collected and used for pricing purposes; and where the learning curve technique was available to estimate future costs. As a result, the use of the incentive contract was in a situation where the aircraft was already designed, previous articles had been manufactured, unusually accurate cost information was available, good pricing techniques were present and the contractor had incurred a substantial amount of experience on the job. The incentive contracts that resulted were normally performed without substantial variation from the negotiated targets.[2]

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[1] Nash p. 3

[2] Nash p. 4

Recent history of incentive contracting has been quite different from that of many years ago. Present incentive contracts cover a group of products much more diverse than in the past. The work in incentive contracts today is forward priced, without the benefit of having started and completed a large amount of the project. These factors make understanding incentives complex and the actual effect of the incentive problematic.[3]

CONSTRUCTION CONTRACTS

A construction contract can be defined as "[a] contract under which one party promises to furnish services and materials to build a structure or to improve real property for another who promises to pay for the work performed."[4] Since construction contracts are typically drafted by the owner of the project and then competitively bid, it is not surprising that the terms of the contract tend to favor the owner. The contractor usually has no say in the terms other than to refuse to bid on the work, an option not favored by most contractors.

The construction contract is made up of three critical elements: scope of work, schedule and price. In a construction contract these three elements are normally described in a large document called the contract documents. The contract documents in turn has five primary elements. These five elements are the Agreement between the Owner and Contractor, General Conditions, Special Conditions (Supplementary Conditions), Drawings and Specifications.[5]

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[3] Nash p. 4

[4] Frein p. 48

[5] Hapke p. 25-26

The Agreement between Owner and Contractor includes references to the owner, contractor and designer along with mailing and business addresses. Frequently there will be a listing of articles setting forth the contract documents applicable to the project; a brief description of the project; dates for commencement and completion; contract price; and other relevant miscellaneous provisions.

The General Conditions is a list of ground rules by which the owner, designer and contractor will abide by during the actual construction. Items contained here include information concerning the status and authority of the designer, owner, contractor and subcontractors; the circumstances under which work may be performed by the owner; rules concerning progress, completion and delays, progress and final payments; insurance, and other miscellaneous provisions.

Special conditions (Supplementary Conditions) are more project specific than General Conditions. The purpose of special conditions is to address variations unique to individual projects, requirements of individual owners and variations in specific legal requirements. Special conditions will frequently cover the same topics as do the General Conditions, only in greater detail.

Fourth, drawings consist of scale and/or schematic drawings depicting the various features of the project which are best described graphically. Drawings are numbered and divided according to the specific elements of the project and the various trades.

Finally, the specification element is a detailed numerical and word description of the work that sets the standard for the quality and quantity of the detailed elements that comprise the entire project. The Construction Specifications Institute (CSI) has developed an industry standard specification system that has sixteen major divisions. Each division deals with a particular trade of work and describes in detail how that work is to be accomplished.

TYPES OF CONSTRUCTION CONTRACTS

Essentially there are two types of contracts: fixed-price and cost reimbursable. The difference between these two contracts is the allocation of risk and the contractor's fee structure.[6]

Incentive contracts take many forms, with the actual incentive relying heavily upon the type of contract being used by the owner. Thus, it is easy to see that an owner that offers a cost reimbursable contract for bid would seriously consider offering an incentive to control costs, so that the owner established financial goals for the project are met. One may argue that almost every contract is a type of incentive contract with the incentive being to make a profit. The firm fixed price contract, which has long been considered the favored contractual form, is the ultimate incentive contract. The incentive being that the contractor accepts the full responsibility for all cost overruns. The only difference between the incentive contract and the firm fixed price contract is that in the use of the

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[6] Workman p. 16

incentive contract, the contractor takes a smaller share of the total cost responsibility.[7]

Other types of contracts encourage different forms of incentives. To illustrate, almost any contract could have an incentive to encourage safety and reduce reportable accidents. The construction industry is inherently a dangerous occupation, and in fact, construction trades traditionally have higher rates of on-the-job accidents then other industries. As a result, workman's compensation and liability insurance for contractors and owners has been at a premium. Contractors who do not promote on-the-job safety quickly find themselves paying outrageous rates for insurance, reducing their ability to competitively bid for future projects. High accident rates have also been known to cause negative public reaction and can impact the positive public image that most owners and contractors find essential. As a result, safety incentives on all types of contracts have become standard among construction industry leaders.

In recent years, schedule incentives have seen a rise in their application in order to meet the demand for new product lines. The fast-track effort to get a product to market from initial conception includes a substantial time for construction of manufacturing facilities. Consequently, positive incentives for on time or early completion and negative incentives for late completion have become popular.

The number of incentives offered by an owner is limited only by the imagination of the contracting officer. Incentives can be given for quality,

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[7] Nash p. 3

schedule, safety, cost, and in sum, just about anything else of significance. One of the most frequently used incentives is an incentive on the cost performance of a contract. Such incentives are the most simple to administer and the easiest to negotiate.[8] The two basic types of contracts used to provide incentives on cost are the fixed price incentive and the cost plus incentive fee contract. The fixed price incentive contract contains a fixed ceiling price, has an unlimited range of sharing of costs and is settled by negotiation of a final "fixed" price near the completion of performance.[9] Conversely, the cost plus incentive fee contract contains no ceiling, has a range of cost sharing limited by the maximum and minimum fee, and is settled by vouchering all costs.[10] However, the incentive formulas in these two types of contracts operate in a similar manner.[11] There are many other types of contracts that use incentives.

The firm fixed price or lump sum contract is the most commonly used contract. As the name implies, this contract is based on a fixed price that is agreed upon before construction begins. The contractor performs all of the work required for construction of the project in accordance with the plans, specifications, and other contractual documents, with the profit included in the lump sum.[12] Usually included in this contract is a negative incentive where the contractor is penalized for failure to meet the completion date.

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[8] Nash p. 8
[9] Nash p. 8
[10] Nash p. 8
[11] Nash p. 8
[12] Hauf p. 11

The cost plus percentage fee contract is a contract where the material, labor, equipment rental, and all other associated costs are tallied up and an additional percentage of this cost is given to the contractor as profit. Since the contractor's profit is a direct percentage of the overall cost, there is little motivation by the contractor to control costs. Thus, cost incentives are popular in this cost plus percentage fee contracts.[13]

The cost plus fixed fee contract is a contract where the contractor receives only the stipulated fee for his part in overseeing and running the job regardless of the cost of the project.[14] Again, there is little motivation to control costs. Consequently, cost incentives are used frequently with this type of contract.

Another type of incentive contract that has become popular is the award fee contract. This type of incentive contract has a base contract, either a fixed-price or a cost contract. The award fee contract has an award fee that is given to the contractor at specified intervals for superior work. The terms of this contract usually specify some arbitrary scale that is used by the owner to measure performance to determine the amount of the award fee. The award fee is optional, with the owner unilaterally awarding an amount that is deemed to represent the contractor's performance. In government contracts this award fee is not subject to a disputes clause.[15] Contracts of this type have typically been used in facility support contracts.

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[13] Dunham p. 131

[14] Dunham p. 132

[15] FAR 16.404-2

Although no contract type is perfect for every situation, there is a natural tendency to prefer a fixed price contract wherever it can be used.[16] This tendency stems from the sense of security in risk allocation and price assurance that an owner perceives and the inherent incentive of a contractor to manage efficiently. In recent years, cost-type contracts have seen a rise in popularity as owners have experienced increased pressure to get new products to market in shorter periods of time. This pressure has resulted in a situation where the schedule for completion becomes the foremost priority. The planning and programming of the project is usually reduced to a minimum, fast-tracking of the project takes place and construction is begun before the design is complete. Consequently, owners, recognizing that an inordinate amount of the risk of the project is being placed upon the contractor, have chosen to use a cost type contract in these situations.

Regardless of the type of contract, the use of incentives must be done judiciously and with the objectives of the project clearly in focus.

TYPES OF INCENTIVES

Negative Incentives/Liquidated Damages

The hypothetical stone-age case and the illustrated firm fixed price contract example described previously both had negative incentives. Negative schedule incentives, in the form of liquidated damages, have been common in the construction industry. Nowhere is the old adage of "time is money" truer than in

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[16] Smith, et al, p. 911

a construction project. An owner develops an expected schedule for occupying a facility based on the construction contract and plans accordingly. Therefore, it is imperative that the facility be completed on time so that the facility can be used.

Sides Construction Company v. City of Scott City, 581 S.W.2d 443 (Mo. App. 1979) illustrates the importance of adhering to the completion date set forth in the contract. In *Sides Construction*, the failure of the contractor to complete a swimming pool forced the city to hire additional engineering personnel and resulted in a loss of revenue on the project for the city. However, in those cases where there is no substantial prejudice to the owner due to the delay of the contractor or the delay is occasioned by mutual error, the courts have been reluctant to award damages.[17]

Another example of the importance of adhering to the terms of the contract is illustrated in *San Ore-Gardner v. Missouri Railroad Company*, 496 F. Supp. 1337 (E.D. Ark. 1980) where the court refused to enforce the liquidated damages clause. The liquidated damages clause was considered to be a penalty by nature. The court deemed that the clause did not appear to be a bona fide attempt by both contracting parties to agree upon a reasonable compensation for any harm which would be caused by delayed performance.

Another case, *Department of Transportation v. Fortune Bridge Company*, 243 S.E.2d 647 (Ga. App. 1978) established a test to aid in determining whether a clause is a valid liquidated damages provision or an invalid penalty. The test established in *Department of Transportation*, is whether the injury caused by the

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[17] Hapke p. 26

breach is difficult or impossible to accurately estimate; whether the parties intended to provide for damages or a penalty; and whether the sum stipulated is a reasonable pre-estimate of the probable loss.[18]

Negative incentives in the form of liquidated damages have been in use for a long time. However, the actual benefit of the negative incentive is questionable, with previous research showing that negative incentives provide little benefit and in some cases can detrimentally affect the project.[19]

Positive Incentives/Bonus Incentives

Contractual incentives for construction are often referred to as being positive in nature when in fact they can be positive, negative or both.[20] Generally speaking, there is no positive incentive without a corresponding negative incentive.

Incentives in construction contracts connote "profit adjustment" to the contractor. They are tied to performance measures and somehow increase or decrease the contractor's profit margin. Tailoring the incentive to the value received by the owner is of great importance.[21] In order to accomplish this the owner must decide what areas of performance are of significant importance. The owner must then determine how to tie the incentive to better contractor performance.

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[18] Hapke p. 27

[19] Workman p. 71

[20] Stukhart, p. 34; BR Report A-7, p. 14

[21] Sykes, p. 63

One area where positive incentives are frequently used is in cost performance. Cost incentives are generally thought of as being a combination of an inducement and a threat. An example is the target type contract where there is a bonus penalty directly tied to the final cost of the construction to the owner.

Among owners, there appears to be a trend to tie performance measures to an encouragement incentive or "bonus only" provision.[22] In fact, some owners believe "that penalty clauses are negative incentives that turn off even the most conscientious of contractors."[23]

Positive incentives as a whole have been endorsed by previous studies. In the study completed in 1985 by B.W. Workman,[24] there was evidence that the use of positive incentives significantly improved contract performance. Despite this, there remains reluctance among owners to fully utilize this type of incentive.

A possible reason for this lies in the inherent disadvantages of positive incentives. Disadvantages include: the owner's difficulty in establishing fair and equitable targets, additional administrative resources, extra negotiations, substantially completed project engineering, difficulty in changing goals and priorities after a contract is awarded and the lack of quantifiable benefits by using the positive incentive.[25] These disadvantages all contribute to make the task of adding incentives to a contract a daunting task.

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[22] Workman p. 25

[23] Sykes, p. 63

[24] Workman

[25] BR Report A-7, p. 14-15

INCENTIVE FEE CALCULATION

The motivation for a contractor to complete a project in a timely manner with adequate quality rests primarily in "pride and profit."[26] Since pride cannot be harnessed and used by the owner, the only motivation that an owner can provide is through the compensation system outlined in the contract.[27] As such, there are many variations of construction contracts that seek to make use of this profit motive.

Due to the fact that a cost based contract does not provide a contractor with motivation to decrease costs in order to earn his fee, cost and fee incentives were devised in order to motivate contractor efforts and to discourage inefficiency and waste. Inefficiency and waste are discouraged by the use of predetermined incentives on performance or delivery coupled with concurrent increases in profit or fee provided for achievement that surpasses the targets, and decreases are to the extent that such targets are not met.[28]

Incentive contracts include a target cost, a target profit or fee, and a profit or fee adjustment formula tied to the relationship between actual reimbursable costs incurred by the contractor and target costs.[29] In lieu of costs, targets may come in the form of a specific performance characteristic such as the production capacity of a manufacturing plant. The following formula establishes what the fee a contractor receives is:[30]

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[26] Smith, et al, p. 911

[27] Workman p. 16

[28] FAR 16.401(b)

[29] FAR 16.403-1 and 404-1

$$F_c = F_t - k (C - C_t) \qquad \text{(Eq. II-1)}$$

Where: F_c = Contractor's actual fee received

F_t = Target fee

C = Actual cost of the project

C_t = Target cost established in the contract

K = Sharing ratio of the contractor

In a pure fixed-price contract the contractor assumes the risk of the outcome of actual project cost ($k = 1$) and the fee received by the contractor equals the target fee per its estimate plus any differential in actual cost below that estimated. The equation can be reduced and expressed as follows:[31]

$$F_c = F_t - (C - C_t) \qquad \text{(Eq. II-2)}$$

In a pure cost-reimbursable contract the owner assumes the risk of actual project cost ($k = 0$) and the fee received by the contractor equals the target fee negotiated.[32] The formula can then be expressed as:

$$F_c = F_t \qquad \text{(Eq. II-3)}$$

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[30] Stukhart, p. 35

[31] Workman p. 17

[32] Workman p. 17

The target fee can be a fixed amount where F_c is a constant or it can be a percentage of the actual cost to the owner and F_c becomes a variable. The number of variations where the sharing ratio is between the extremes of one and zero is unlimited. This type of fee structure implies a sharing of any cost over-run or under-run, subject to any imposed limitations, and hence has been labeled as a cost incentive contract. A typical fixed price incentive contract or cost plus incentive fee contract will have a sharing arrangement illustrated by the following example:

Fixed Price Incentive Contract

Target Cost	$100
Target Profit	9%
Ceiling Price	121%
Sharing Arrangement	75/25

Cost Plus Incentive Fee Contract

Target Cost	$100
Target Fee	6%
Maximum Fee	10%
Minimum Fee	2%
Sharing Arrangement	85/15

The target cost in either type of incentive contract is usually the focal point of the contract since it is the accepted practice to attempt to arrive at a mutual acceptable target cost before establishing the remainder of the formula.[33] The target cost is also important in the operation of the incentive formula since it is the fulcrum around which the formula revolves. The formula states that if

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[33] Nash p. 9-12

actual costs exceed target costs, profit is reduced and if actual costs are less than target costs, profit is increased. Hence, the target cost is the basis for setting the profit or fee and also serves as point around which profit fluctuates during contract performance.[34]

Figures II-1 and II-2 show the graphical representation of the typical fixed price incentive contract and the cost plus incentive fee contract for the formulas discussed above. These graphs depict the actual amount of profit to be paid to a contractor at any level of the actual cost incurred in the performance of a contract.[35]

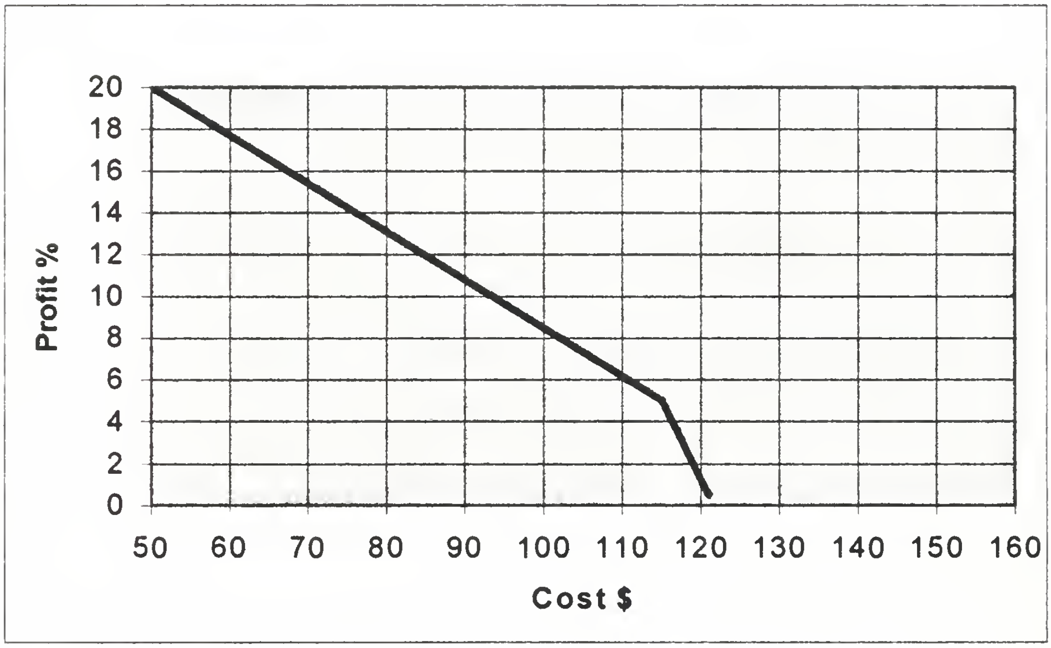

Figure II -1, Fixed Price Incentive Contract Fee Graph

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[34] Nash p. 12

[35] Nash p. 10-12

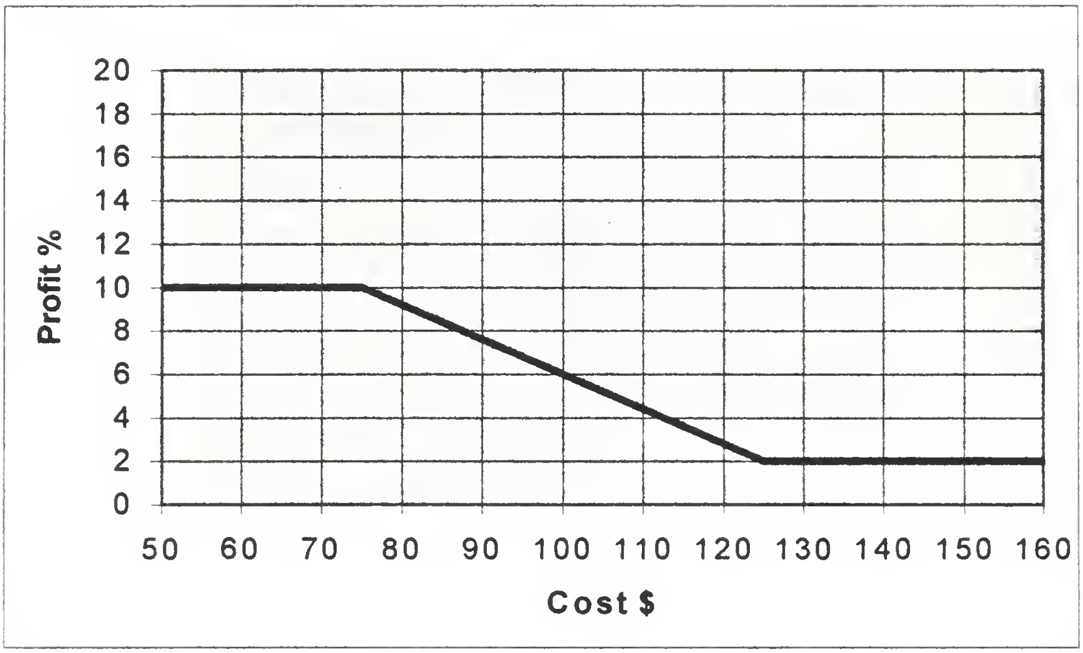

Figure II - 2, Cost Plus Incentive Contract Fee Graph

INCENTIVE FEE GOALS

The objective of incentive programs should be to promote the goals of the owner and "to produce a harmonious relationship between the owner and contractor [in order] to achieve beneficial end results for both."[36] To promote this type of relationship between owners and contractors, owners should seek input from the contractor on how best to implement the goals of the owner. The following is list of seven elements for a successful incentive program:[37]

> The owner thoroughly thought out the objectives and established priorities with the contractor

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[36] Carmody, p. 33

[37] Carmody, p. 34

participating in establishing appropriate incentives;

Sufficient time was spent to adequately measure accomplishments;

Arrangement was agreed upon at the initiation of the contract;

The method of setting targets was specified when actual target values are to be established at a later time;

Written rule prevented continual nitpicking;

The contractor was in control of the situation as soon as the measures of performance were determined; and

Targets were established to reflect competent performance with some tolerance for error and contingency.

The goals of an incentive program must be to "motivate the contractor to produce a system that will meet or surpass performance goals, on or before a target date, and within a target cost."[38] "Competence must therefore be the benchmark, or the null point, from which positive incentives can be set for performance which is clearly superior to the benchmark."[39] Incentives should be designed so that a win-win situation exists between the contractor and the owner. If the incentive program is skewed towards one party then the feeling of being cheated will exist. If the contractor feels that an incentive is an impractical goal, not financially worth pursuing, then the purpose of the owner in including an incentive has been defeated. On the other hand, if an incentive unduly awards the contractor additional profit for little additional performance, then the owner will

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[38] Finchum, p. 389

[39] Carmody, p. 33

find any contractor request for additional compensation, even if warranted, difficult to accept.

PREVIOUS RESEARCH RESULTS

In September 1959 a survey by the San Francisco section of the American Society of Civil Engineers (ASCE) Construction Division was conducted. The basic objective was to determine current practices in contracting administration.[40] This research was performed on San Francisco area ASCE members using a forty-eight-question survey. A total of 300 respondents completed the survey. Survey results showed that for construction contracts, 75 percent use liquidated damages provisions and 77 percent do not provide bonus provisions.

The study of the ASCE concluded that the current practice of using liquidated damage clauses is believed to lead to overall contract economy. In addition, the committee concluded that current practice does not provide bonus provisions or invite proposals with optional or alternative completion times.

A second research study conducted by Billy Wayne Workman, Jr. in 1985 utilized survey responses from Construction Industry Institute companies.[41] The survey consisted of 36 completed questionnaires. The study determined that safety performance is better for contracts with positive incentives. Schedule performance was also shown to be better for contracts with positive incentives than for contracts with negative incentives. Other performance measures also

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[40] Special Committee, p. 1

[41] Workman, p. 71

appeared to yield better results where positive incentives were employed instead of negative incentives. Negative incentives appeared to hamper project performance, and in fact, appeared to lower performance outcomes below the level attained by contracts with no incentives.

Chapter 3

Data Gathering by the Construction Industry Institute

This CII data was collected from CII member companies from two separately conducted surveys. Each survey consists of two questionnaires. One questionnaire was addressed to CII Construction Companies that did the actual construction; the other was sent to CII member companies that were the owners of the projects. No effort was made to obtain data from an owner and a contractor on the same project, although the possibility that data from two different sources on the same project exists.

Data from these questionnaires was collected by CII and formatted into spreadsheets with all company names deleted to provide confidentiality.

FIRST CII SURVEY

The CII Benchmarking and Metrics Committee performed the first round of data collection and analysis in 1996 (version 1.0). In this data collection effort, 22 owner companies and 25 contractor companies, all members of CII, participated by submitting 94 projects and 119 projects, respectively. These projects represent $11.5 billion of total cost in the heavy industrial, light industrial, infrastructure, and building groups within the construction industry. The response rate for projects submitted was approximately 4.5 projects per

participating company. A total of 213 projects that met specified criteria were submitted in this first round of data collection. Table III -1 provides a summary distribution of the types of projects submitted.[42]

	Owners	**Contractors**	**Total**
Buildings	20	13	33
Heavy Industrial	51	71	122
Infrastructure	9	23	32
Light Industrial	14	12	26
Total	94	119	213

Table III - 1, Summary of Project Distribution, First Survey

While an owner is responsible for the entire project, from conception to operation, a contractor only has responsibility for a portion of the total project. Figure III - 1 shows the contractor's responsibility for the 119 projects submitted. It should be noted that the contractors in each category might have responsibility for all or only a portion of the functions in question.[43]

The overall cost of the projects in this database ranges between $5 million and $500 million in project capitalization. As shown in Figure III - 2, approximately one-third of the contracts had a cost of less then $15 million, one-third had a cost between $15 million and $50 million and one-third had a cost in excess of $50 million.[44]

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[42] Benchmarking Report p. x

[43] Benchmarking p. 8

[44] Benchmarking p. 11

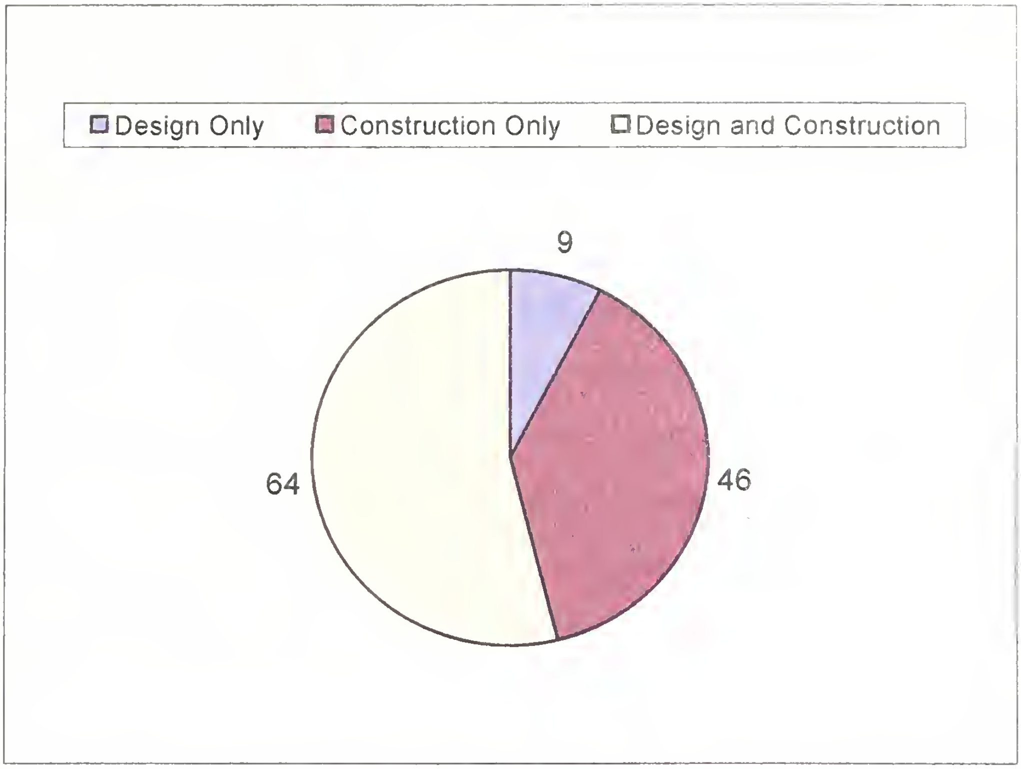

Figure III - 1, Contractor Functions, First Survey

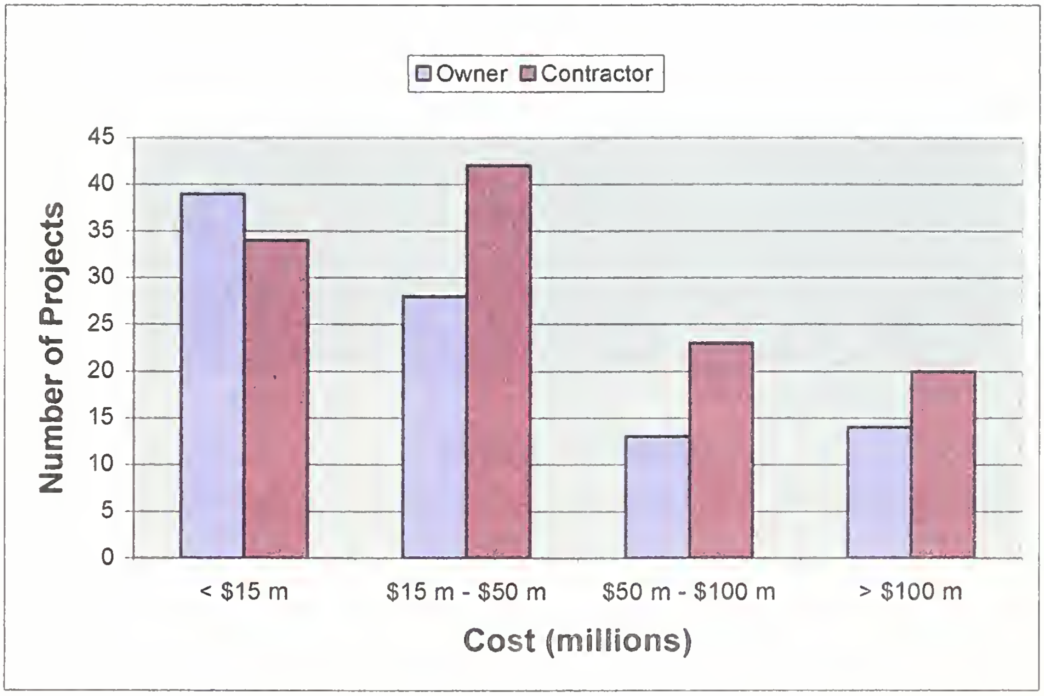

Figure III - 2, Distribution of Project Cost, First Survey

Projects in the database can be categorized by what is called the "nature" of the project. This is a categorization based on whether the project is a grass roots project, an addition, or a modernization. With the definition of these terms being that a grass-roots project is a new facility; an addition being a project which ties into an existing facility; and a modernization a project for which a substantial amount of equipment or structure is replaced or modified. Figure III - 3 illustrates the nature of the project data submitted.[45]

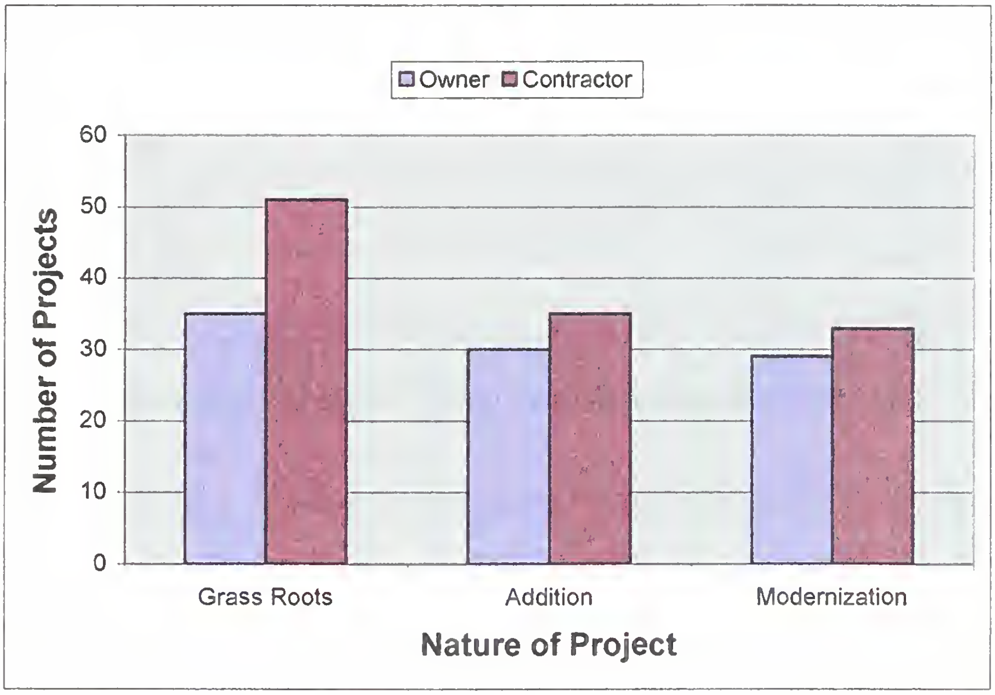

Figure III - 3, Nature of Projects, First Survey

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[45] Benchmarking p. 11-12

SECOND CII SURVEY

The CII Benchmarking and Metrics Committee followed up the first round of data collection with a second round performed in 1997 (version 2.0). In the second data collection effort, 22 owner companies and 19 contractor companies participated by submitting 90 projects and 94 projects, respectively. These projects represented $9.1 billion of total cost within the heavy industrial, light industrial, infrastructure, and building groups of the construction industry. A total of 184 projects that met specified criteria were submitted in this survey. Table III -2 provides a summary distribution of the type of projects in this database.[46]

	Owners	**Contractors**	**Total**
Buildings	21	4	25
Heavy Industrial	48	80	128
Infrastructure	6	2	8
Light Industrial	15	8	23
Total	90	94	184

Table III - 2, Summary of Project Distribution, Second Survey

Figure III - 4 shows the contractor's responsibility for the 94 projects submitted in the second survey. It should be noted that the contractors in each category might have responsibility for all or only a portion of the functions in question.[47] It should also be noted that the 2nd survey consisted of more design and design and construction contracts than the first survey.

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[46] Morrow

[47] Benchmark p. 11

Chapter 4

Analysis Methodology

BACKGROUND

Since a contract can have negative incentives, positive incentives or a combination of both types of incentives, any examination of the effects of incentives must be done from a macro perspective. An examination of the "big picture," in which the effects of the incentives as a whole on construction contract performance is studied, should provide beneficial results. An analysis of the effect of individual incentives on specific areas of a project will be conducted where the data is sufficient to enable a comparison between contracts with and without incentives.

The information for this study was taken from the raw data of each project and examined by the type of incentive offered in the construction phase. The construction phase is the primary phase in which the largest amounts of resources are committed. Traditionally less then 5% of the total project cost is committed to the pre-project planning. An additional 15% of the total cost is used for the design effort.[48] Therefore, the total construction effort including procured equipment totals approximately 80% of the cost of a project.

An examination of the construction phase should provide the most potential return. Also, data compiled from the contractors would only support a

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[48] Metrics, notes 3/31/97

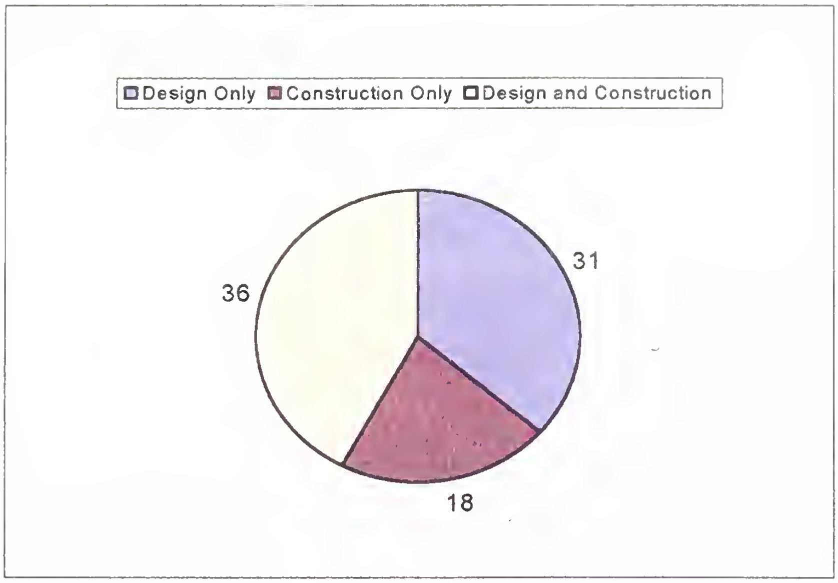

Figure III - 4, Contractors Functions, Second Survey

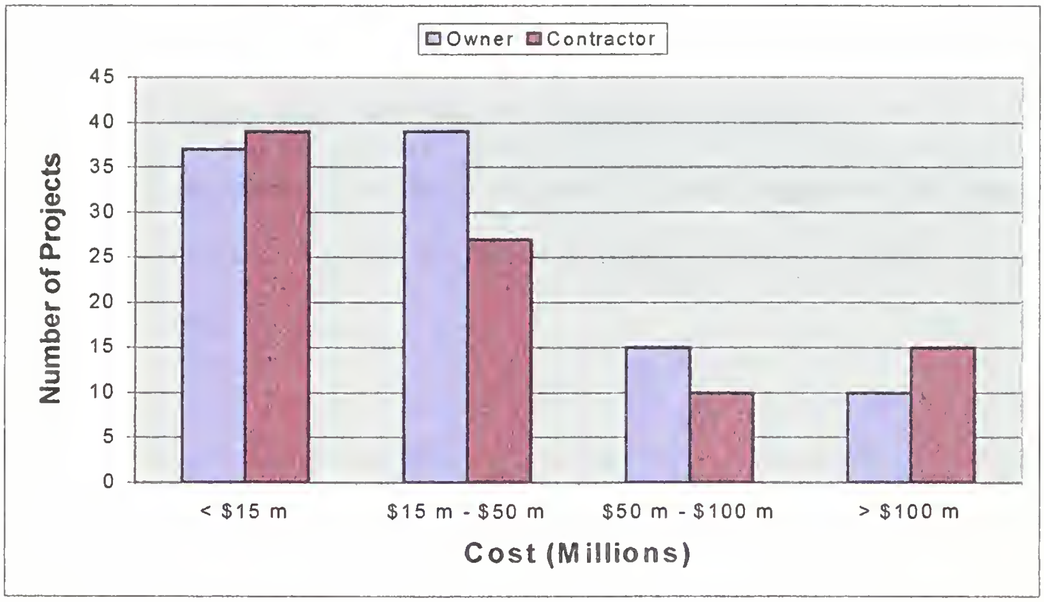

Figure III -5, Distribution of Project Cost, Second Survey

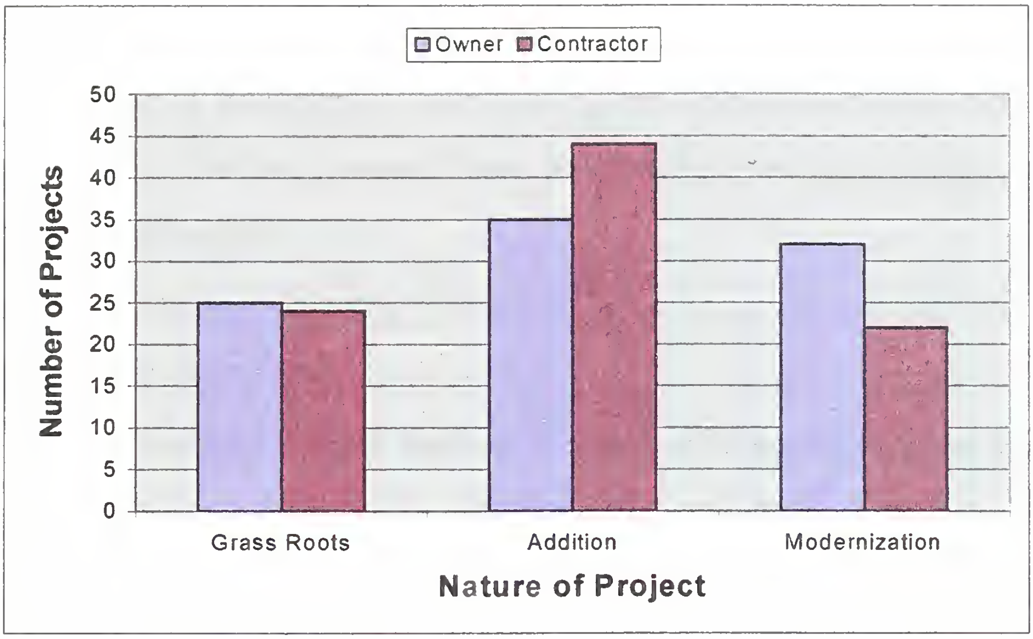

Figure III - 6, Nature of the Projects, Second Survey

Figure III - 5 shows the cost distribution for the projects in the second survey and Figure III - 6 shows the nature of the projects in the second survey.

construction phase analysis since many contractors had no knowledge or involvement in the pre-construction phases of the project. An examination of the effect of incentives on other phases such as the design phase could be accomplished by developing or modifying the cost, schedule and safety factors that are being used for the construction phase analysis and then utilizing the owner data for analysis.

FIRST SURVEY QUESTIONS

The first survey by CII consisted of a total of 38 questions dealing with many aspects of a construction project. This study will only use a small portion of the available data in the analysis of the effect of incentives. The data from questions that will be used are:

1) Incentive Data from Question 11
2) Cost Data from Questions 12, 13, and 14
3) Schedule Data from Question 15
4) Safety Data from Question 18

SECOND SURVEY QUESTIONS

The second survey conducted by CII consisted of a total of 41 questions. As in the first survey, these questions deal with many aspects of these construction projects. Questions from the second survey that will be used are:

1) Incentive Data from Question 10
2) Cost Data from Questions 11a, 12, 13
3) Schedule Data from Questions 14, 15
4) Safety Data from Questions 18 thru 34

ANALYSIS PLAN

The analysis will begin by separating the contracts with cost incentives v. contracts without cost incentives. These contracts will then be further grouped based on the type of cost incentive. Contracts with positive, negative or both positive and negative incentives will be grouped together for the analysis. The same separation for contracts with and without both schedule and safety incentives will also be undertaken. The data will be further examined by subdividing the data from each survey into owner and contractor data for examination.

Once the projects have been subdivided, calculation of the factors to be used for analysis will be done. Budget Factors, Cost Growth Factors, Schedule Factors, Schedule Growth Factors, Reportable Incident Rate (RIR) and Lost Workday Case Incident Rate (LWCIR) will be calculated for each project. Specific formulas for each of these factors are as follows:

Cost Analysis

1) Budget Factor = Actual Cost /(Authorized Cost + Change Order Cost)
2) Cost Growth = Actual Cost-Authorized Cost/Authorized Cost

Schedule Analysis

3) Schedule Factor = Actual Schedule/(Estimated Schedule + Change Order Schedule)
4) Schedule Growth = Actual Schedule-Estimated Schedule/Estimated Schedule

Safety Analysis

1) RIR = Recordable Incidents * 200,000/Work Hours
2) LWCIR = Lost Workday Cases * 200,000/Work Hours

The mean (average), median, standard deviation and variance will then be calculated for each of the factors in an attempt to determine the statistical validity of the data. The validity of the data will further be examined by looking at the distribution of the data using histograms. Histograms for each factor for both owners and contractors will be developed to see if the data is normally distributed plots. An additional examination of the calculated factors will then be done using the statistical F-test methodology. The F-Test is used to determine if statistical significance is exhibited by the data. The F-test for significance is calculated using the formula:

$$F = (BSS/DF) / (WSS/DF)$$

Where: BSS = Between Sum of Squares
WSS = Within Sum of Squares
DF = Degrees of Freedom (N-1) or (k-1)

A comparison of the values calculated and these critical values for the population, with one degree of freedom, will be accomplished. The calculated F-test value must meet the critical F-test value to show that a clear difference between projects with and without incentives exists. The critical values that will

be used in this evaluation are standard and can be referenced in almost any statistics book[49]. In the case that the data does not meet the F-test, then further examination to determine causation will be attempted. Although the data might not meet the F-Test, that does not mean that the data is not valid. Failure of this test means that although a clear-cut difference between the data does not exist statistically, there can still be obvious trends that can be observed. A further analysis of possible trends based on these observations, whether the F-test is met or not, will be done.

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[49] Moore, p 630

Chapter 5

Analysis of Data

PROJECTS WITH INCENTIVES

The projects included in the CII database consisted of different types of contracts. Many of these contracts include contractors that do not directly supervise craftsmen. Therefore, only those contractors that had direct control over the construction of the project could be included in this examination. Contractor functions that were included consisted of general contractors, prime contractors, sub-contractors or those contractors involved in demolition work.

The primary objective of this research is to compare projects with positive, negative, or a combination of positive and negative incentives versus contracts with no incentives in the areas of cost, schedule and safety. Therefore, the budget factor and the cost growth factor will be used to provide an analysis of the effect of cost incentives. Similarly, the schedule factor and the schedule growth factor will be used for evaluation of schedule incentives and the reportable incident rate (RIR) and lost work day incident rate (LWCIR) will be used to grade the performance of safety incentives.

This examination will not evaluate performance in areas not directly affected by the incentive being offered. For example, contracts with a cost incentive will only be evaluated by examining the budget and cost growth factors. Attempting to evaluate these cost incentive projects for safety or schedule

performance, without including a process by which possible incentives for safety or schedule are included would provide highly inaccurate results.

Not all contracts included in this database had incentives. In fact the majority did not have any type of incentives. Table V - 1 shows all the projects in this database arranged by the type of incentive in the construction phase. This table also separates the data from the first and second surveys and separates the data by contractor and owner. An examination of this table shows that this database consists of 397 projects on which data was obtained. It should also be noted that while the number of projects with positive, negative, both positive and negative or no incentives is sufficient to provide accurate results, there are a number of incentive types that have a limited number of projects.

Some types of incentives are not commonly used in the construction industry. As Table V - 1 illustrates; negative cost and safety incentives are rarely used. Although this study will use the available projects in these areas to perform an analysis, the results are prejudiced by the limited data for these types of projects. Therefore, any conclusion must be taken in the context of this limitation. All other contract incentive situations have sufficient data to provide results with a high confidence level in the accuracy of those results.

Another limitation that was evident was the fact that some projects included in the database have insufficient or non-existent data in certain areas needed for this examination. Some of the projects submitted did not have cost data, schedule data, or safety data. In those situations, the project was only used

Survey		**Number of Projects w/Incentives (Construction Phase)**			
		Type of Incentive	**Cost**	**Schedule**	**Safety**
Contractor	First Survey	Positive	30	31	25
		Negative	3	19	2
		Both	16	25	7
		None	70	44	85
		Sub Total	119	119	119
	Second Survey	Positive	15	11	12
		Negative	2	9	1
		Both	2	2	0
		None	75	72	81
		Sub Total	94	94	94
Owner	First Survey	Positive	16	15	27
		Negative	0	9	0
		Both	4	7	1
		None	74	63	66
		Sub Total	94	94	94
	Second Survey	Positive	12	13	15
		Negative	1	3	6
		Both	7	7	51
		None	70	67	18
		Sub Total	90	90	90
		Total Contractor	213	213	213
		Total Owner	184	184	184
		Total	397	397	397

Table V - 1, Projects with Construction Phase Incentives

for those parts of the research where the data was sufficient. As a result, each of the factors as calculated is based on a different number of projects, depending on how many projects had sufficient data. Although this did reduce the overall number of projects with incentives, the data was still sufficient to provide accurate results in all areas except in those mentioned above.

CALCULATION OF FACTORS

The metrics used in this examination provide a basis for comparison. Six factors were used to evaluate cost, schedule and safety performance. The cost and schedule factors used were developed by the Construction Industry Institute, although they have been modified to examine only the construction phase of each project. These factors provide a unique prospective into the "health" of these projects.

The budget factor used herein is a ratio of the actual construction cost of the project to the budgeted construction cost plus the cost of authorized change orders. A budget factor of unity (1.0) represents perfect predictability. A value of less than unity represents cost under-run, while a value greater than unity represents cost overrun.

The cost growth factor used is the ratio of the difference between the actual construction cost of the project and the construction budget to the construction budget. Cost growth measures financial predictability with no allowance for changes. The primary difference between budget factor and cost growth is the inclusion of the change order cost in the budget factor.

The two safety performance metrics used are the recordable incident rate (RIR) and the lost workday case incident rate (LWCIR). The definition of these two factors is identical to those as defined by the Occupational Safety and Health Administration (OSHA). RIR being recordable incidents times 200,000 divided by the total work hours for the project. LWCIR is similarly defined as lost workday cases times 200,000 divided by total project work hours.

[illegible]

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The schedule factor used is a measure of duration predictability. The schedule factor is derived from the ratio of the actual construction duration to the predicted construction duration plus change order impact. A schedule factor of unity represents perfect predictability, a value less then one represents a schedule under-run while greater then one is a schedule over-run.

Schedule growth is a ratio of the difference between the actual total duration of the construction and the predicted construction duration to the predicted construction duration. Schedule growth measures duration predictability with no allowances for owner changes. The difference between schedule factor and schedule growth is that schedule factor includes owner authorized changes while schedule growth does not.

The factors for all projects were calculated and tabulated by first or second survey and by owner or contractor. Due to limitations on the number of incentive projects in some areas, the analysis will examine all results based on all the available data. Data calculations for each sub-division are provided in Appendix A.

COST INCENTIVE ANALYSIS

Table V - 2 shows the calculated factor analysis that was completed for projects with cost incentives. Note that this table is a summary of all the data collected from both contractors and owners. As this indicates, the total number of contracts with negative incentives that could be used for analysis ranged from six

Cost Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner and Contractor, First and Second Survey	***Both Positive and Negative Incentives***	**N**	25	25	24	24	25	24
		Mean	1.01	0.14	1.04	0.09	5.49	0.75
		Median	1.00	0.02	1.01	0.07	4.02	0.19
		Std. Deviation	0.25	0.42	0.24	0.23	4.57	1.16
		Variance	0.06	0.17	0.06	0.05	20.91	1.34
		F-Test v. Without	0.00	0.66	0.35	0.54	0.01	0.00
		F-Test v. Neg.	0.49	0.45	0.44	0.38	0.91	0.88
		F-Test v. Pos	0.03	0.05	0.25	0.74	0.00	0.00
	Positive Incentives	**N**	53	59	50	61	64	63
		Mean	1.02	0.15	0.99	0.03	5.05	0.88
		Median	1.00	0.05	0.98	0.00	2.09	0.00
		Std. Deviation	0.17	0.61	0.20	0.25	8.64	2.31
		Variance	0.03	0.37	0.04	0.06	74.72	5.35
		F-Test v. Without	0.00	0.00	0.60	0.71	0.11	0.85
		F-Test v. Neg.	0.04	0.11	0.68	0.45	0.15	0.12
	Negative Incentives	**N**	6	6	4	4	5	5
		Mean	1.10	0.25	1.01	0.21	4.96	0.77
		Median	1.08	0.34	0.99	0.12	4.00	0.37
		Std. Deviation	0.30	0.29	0.14	0.30	4.05	1.01
		Variance	0.09	0.09	0.02	0.09	16.39	1.02
		F-Test v. Without	0.48	0.53	0.59	0.50	0.25	0.10
	Without Incentives	**N**	213	216	193	211	188	188
		Mean	1.04	0.13	1.00	0.08	4.96	0.95
		Median	0.99	0.06	1.00	0.02	2.99	0.00
		Std. Deviation	0.41	0.40	0.21	0.26	7.39	2.37
		Variance	0.17	0.16	0.04	0.07	54.57	5.61

Table V - 2, Factors Calculated for Projects with Cost Incentives

to four projects. Other types of incentives had at least 24 projects upon which to base the analysis. Means, medians, standard deviations and variance were also calculated. An F-Test analysis, which compares each type of incentive to the other types of incentives and to projects without incentives was also completed.

The statistical validity of the data used was determined by the use of histograms. The data, when plotted, should have a tendency to take on a "bell-shaped" or normal curve distribution. Figure V - 1 is the histogram showing an analysis for the budget factor. Figure V - 1 plots the frequency versus budget factor for projects with positive, negative, both positive and negative and projects without cost incentives. As the histogram plot indicates, the data shows a normal

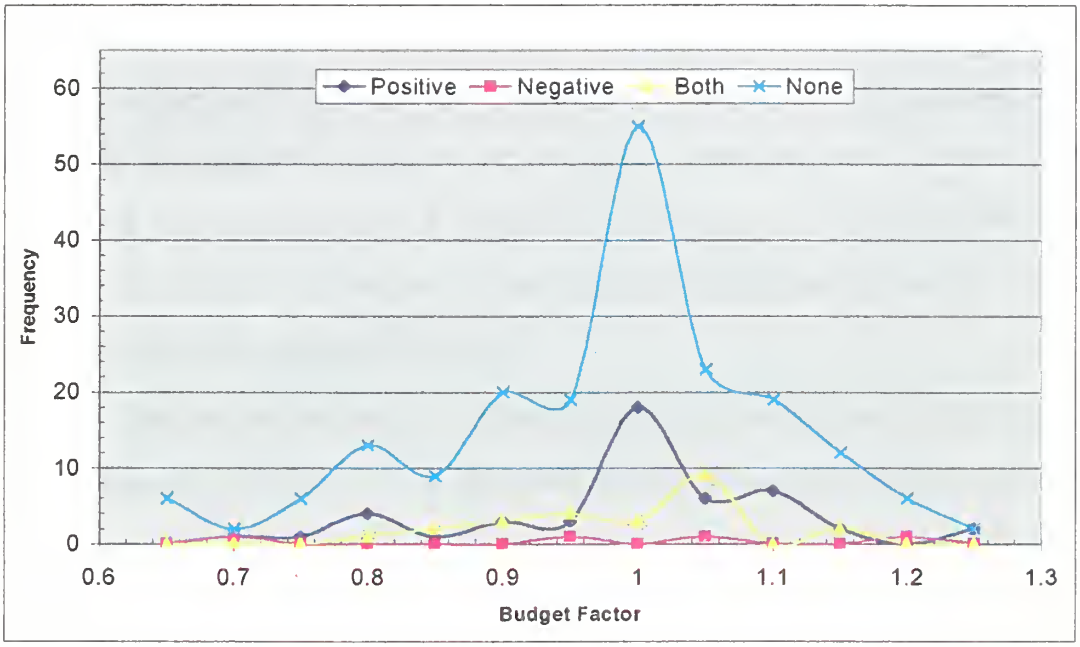

Figure V - 1, Histogram, Cost Incentives Effect on Budget Factor

curve for projects with positive incentives, positive and negative incentives, and projects with no cost incentives. The plot for projects with negative incentives has insufficient data to make any conclusions. Arguably, sufficient data on projects with negative incentives would provide results similar to those obtained for the other types of incentives. This histogram demonstrates that the data obtained is valid and that the results are meaningful.

The budget factor axis of symmetry for positive and no incentive projects is on or about a budget factor value of 1.0. As previously noted, this is the point of high predictability or the unity value. At this point the project budget is approximately equal to what was predicted. The results for projects with both positive and negative incentives are less clear. Here the curve appears to be centered on a vertical axis at a budget factor of about 1.05. This indicates that contracts with a combination of both types of incentives appear to be less predictable, and experience over-runs.

The cost growth factor is the other measure by which cost incentives will be examined. Figure V - 2 is a histogram plot for each type of incentive for the cost growth factor. As shown in this figure, the plots have normal curve tendencies. Interestingly, there appears to be a "dip" in the curve at the cost growth value of 0.1 for projects with no incentives or positive incentives. Also, the plot for both types of incentives shows a drop off at a cost growth value of 0.1. At this time it is unknown what factors are causing this behavior. Overall this plot indicates that cost growth seems to be normally distributed, but that there may be other factors affecting cost growth that separates the projects into those

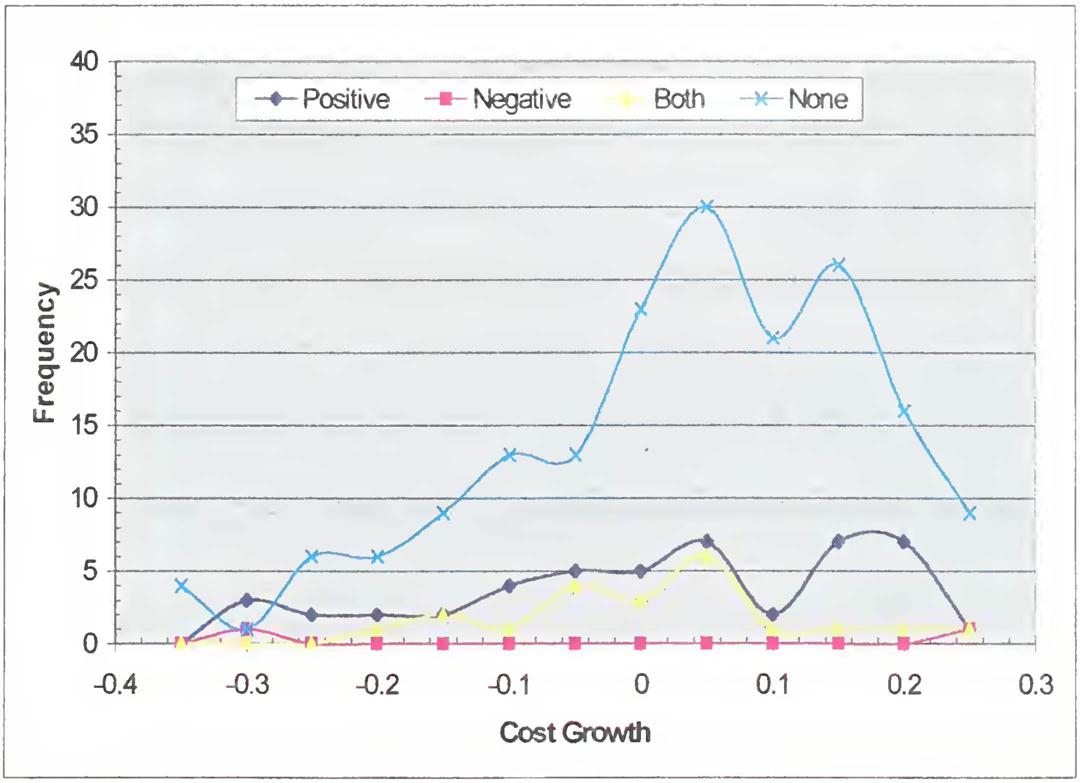

Figure V - 2, Histogram, Cost Incentives Effect on Cost Growth Factor

that slightly exceed the predicted cost and those that significantly exceed the cost prediction. No conjecture on this can be made without sufficient examination of these projects and close study of other influencing factors. Despite this deviation, the results of this study can still be expected to produce acceptable results.

The second statistical tool that was used to provide an evaluation of the significance difference in the data was the F-test. F- test factors were calculated to determine if the data exhibited significant differences based on the type of incentive. An evaluation of the F-test values, as calculated, and the critical F-test

values shows that none of the F-test values meet the critical value to show significant difference in the data. Although this test is not met, it could be that the effects of cost incentives are very small, small enough that the F-test would not be able to differentiate between contracts with or without incentives. This result is not unexpected. Since a construction project has many expenses that are not affected by cost incentives, the potential for improvement upon these factors would be measured in small increments. Small changes such as this would not be noticeable to the F-test, which looks for significant differences between the data

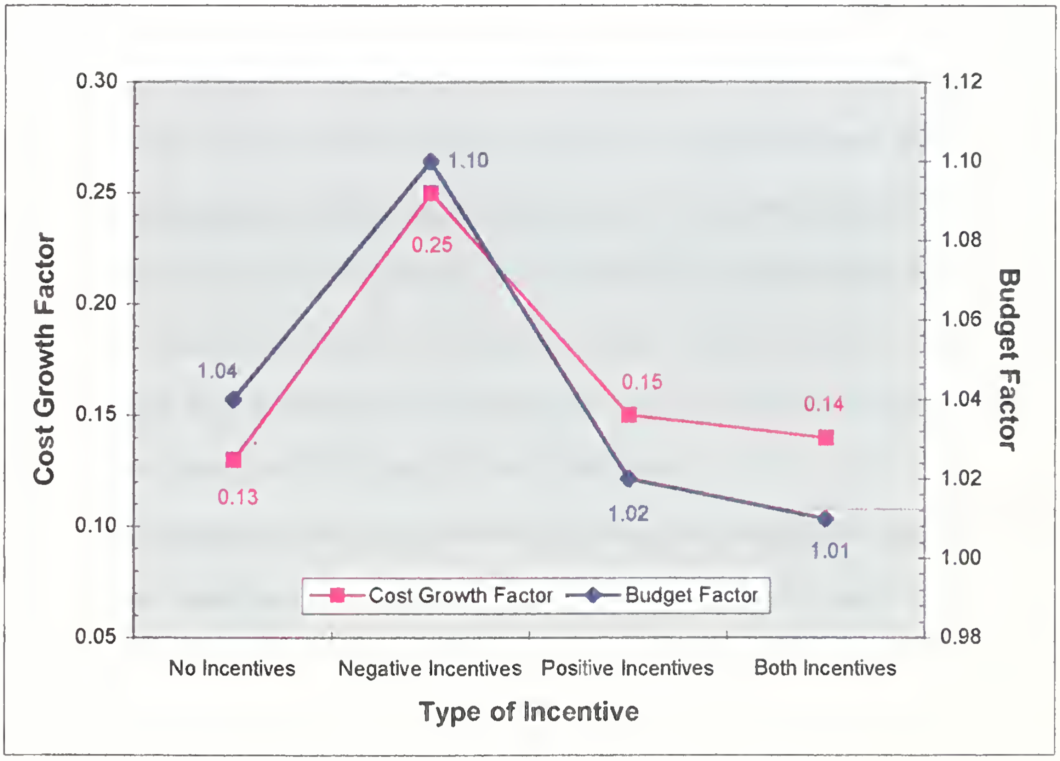

Figure V - 3, Effect of Cost Incentives on Budget and Cost Growth Factors

arrays being compared.

A trend analysis of the budget and cost growth factors was then completed. The potential increases or decreases of the budget factor and the cost growth factor, based on the type of incentive, is shown in Figure V - 3. Figure V - 3 illustrates that the type of incentive employed does have an effect on the cost performance of the project. As can be seen, the budget factor showed only small increases for projects with a combination of incentives over those with a positive incentive and larger increases over projects with negative or no incentives. This would appear to substantiate the hypothesis that contracts with both positive and negative incentives would have the best cost performance. Positive incentives also performed well, showing corresponding increases in performance over those contracts with negative incentives or no incentives. This substantiates the hypothesis that those contracts with positive incentives have better cost performance than projects with negative incentives or projects with no incentives. Negative incentives did not perform as theorized, with significantly lower cost performance than those projects with no incentives. This is directly in contrast to the hypothesis that theorized that projects with negative incentives have slightly better cost performance then those with no incentives.

The cost growth analysis shows a similar graph for positive, both positive and negative incentives and no incentives. The cost growth trend shown here indicates either no improvement, or slightly lower performance than projects with no incentives. As with the budget factor, the cost growth factor for negative cost

incentive projects showed significantly inferior performance results than projects with any other type of incentive.

This trend analysis shows that a positive or both positive and negative cost incentives can provide some benefit to cost performance. More importantly though, this graphically shows that the use of negative cost incentives leads to significantly decreased cost performance. For these projects, the use of negative cost incentives leads to a projected cost growth increase of 12% and a budget factor increase of 6%. Thus, the use of negative cost incentives should be avoided.

SCHEDULE INCENTIVES

Table V - 3 shows the calculated factor analysis that was completed for projects with schedule incentives. As with the cost incentive analysis, this table is a summary of all the data collected from both contractors and owners on both surveys. The total number of projects for each type of incentive is evenly distributed, with at least 32 projects available for each factor analysis. Means, medians, standard deviations and variance were calculated for each of the factors. The F-Test analysis that compares each type of incentive to the other types of incentives and to projects with no incentives is also shown.

The statistical validity of the data used was determined by the use of histograms. Figure V - 4 plots the frequency versus schedule factor for projects.

Schedule Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner and Contractor Data, First and Second Survey	***Both Positive and Negative Incentives***	**N**	36	38	34	37	39	39
		Mean	1.03	0.12	0.85	0.02	5.50	1.12
		Median	1.00	0.03	0.93	-0.01	3.04	0.09
		Std. Deviation	0.24	0.28	0.41	0.22	4.85	3.72
		Variance	0.06	0.08	0.17	0.05	23.56	13.83
		F-Test v. Without	0.00	0.00	0.25	0.08	0.00	0.00
		F-Test v. Neg.	0.00	0.01	0.51	0.03	0.25	0.08
		F-Test v. Pos	0.39	0.00	0.04	0.11	0.29	0.00
	Positive Incentives	**N**	45	55	48	58	59	58
		Mean	0.97	0.13	0.89	0.00	3.63	0.65
		Median	0.99	0.04	0.95	0.00	2.13	0.00
		Std. Deviation	0.21	0.62	0.30	0.17	4.16	1.81
		Variance	0.04	0.39	0.09	0.03	17.34	3.27
		F-Test v. Without	0.00	0.00	0.00	0.00	0.00	0.42
		F-Test v. Neg.	0.00	0.00	0.21	0.00	0.02	0.01
	Negative Incentives	**N**	35	37	32	34	34	34
		Mean	1.01	0.12	0.81	0.11	5.75	1.88
		Median	1.00	0.12	0.98	0.07	4.04	1.01
		Std. Deviation	0.10	0.18	0.37	0.31	5.88	2.75
		Variance	0.01	0.03	0.14	0.10	34.56	7.58
		F-Test v. Without	0.00	0.00	0.06	0.30	0.00	0.00
	Without Incentives	**N**	162	180	155	176	149	151
		Mean	1.02	0.14	0.75	0.10	3.85	0.73
		Median	0.98	0.05	0.95	0.02	3.12	0.00
		Std. Deviation	0.46	0.44	0.49	0.28	20.96	1.66
		Variance	0.21	0.19	0.24	0.08	439.34	2.77

Table V - 3, Factors Calculated for Projects with Schedule Incentives

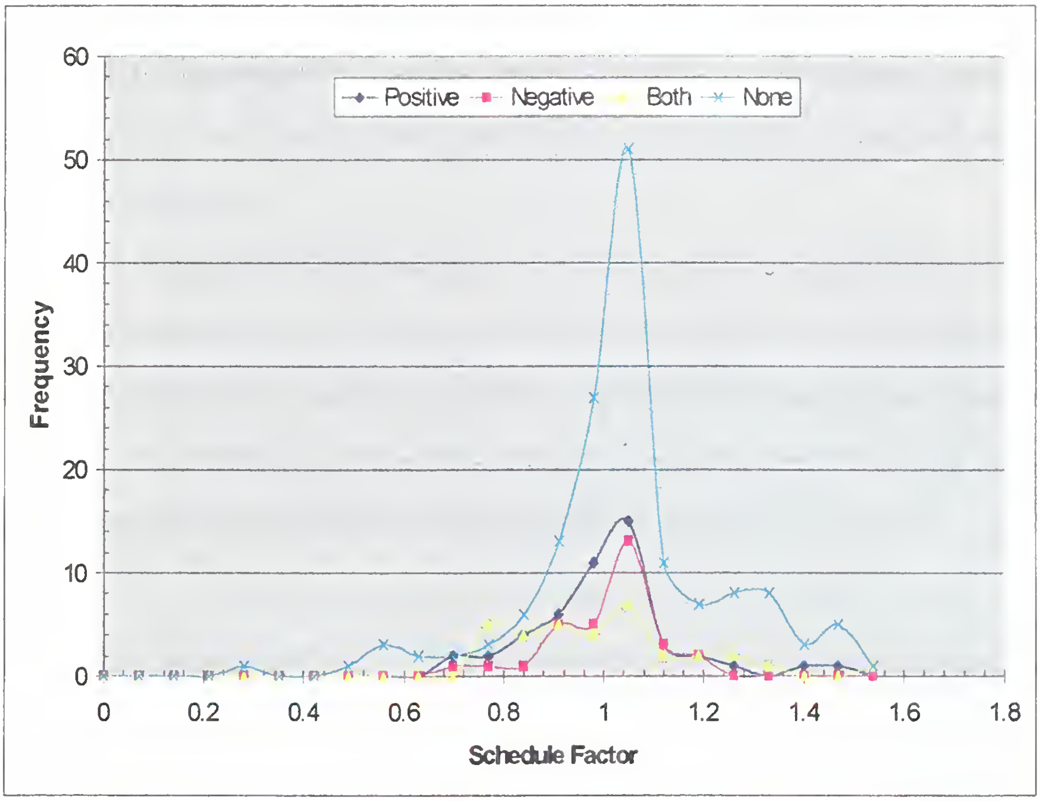

Figure V - 4, Histogram, Schedule Incentives Effect on Schedule Factor with positive, negative, both positive and negative, and projects without schedule incentives

This histogram shows a normal distribution with a symmetrical vertical axis located at a schedule factor value of 1.0 or unity. Again this is not surprising since the majority of projects are completed reasonably close to the intended completion dates. Figure V - 5 is the histogram for the effect of schedule incentives on schedule growth. As shown, the data is normally distributed with a vertical axis at a schedule growth value of 0.0. Since this measures the actual

Figure 4 - 4. Histogram, [illegible]

with positive, negative, both positive and negative, and neutral incentives, [illegible]

incentives.

The histogram [illegible]

axis located as a [illegible]

since the [illegible]

completion [illegible] Figure 4 - [illegible]

incentives [illegible]

vertical [illegible]

schedule growth of the construction phase, and since most projects finish at or very close to the original completion dates, this result is not unusual. Both of these graphs show that the data is valid, normally distributed data with good analysis potential.

The second statistical tool that was used to provide an evaluation of the significance difference of the data was the F-test. F-test factors were calculated to determine if the data exhibited significant differences based on the type of incentive. An evaluation of the F-test values as calculated and the critical F-test values shows that none of the F-test values meet the critical value to show

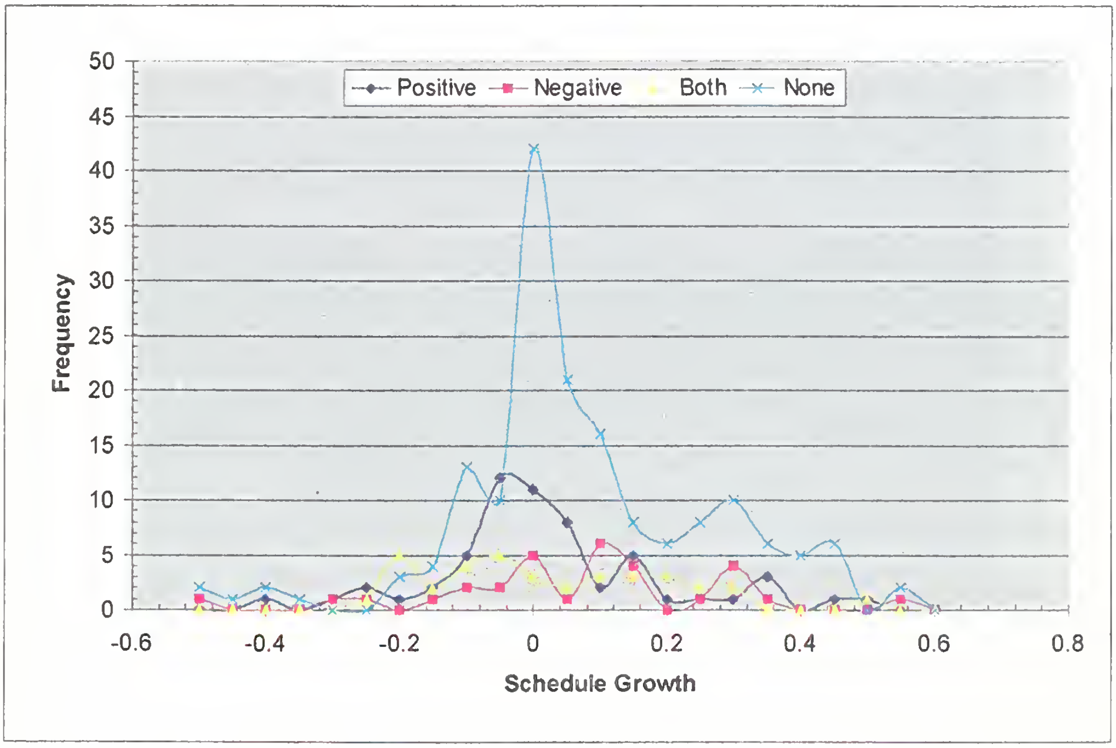

Figure V - 5, Histogram, Schedule Incentives Effect on Schedule Growth

significant difference in the data. It is hypothesized that the effects of schedule incentives are very small, and that an F-test would not be able to differentiate between contracts with or without schedule incentives.

The trend analysis for the effect of schedule incentives on schedule factor and schedule growth is shown in Figure V - 6. For the schedule factor, the effects of both negative and positive incentives caused a reduction in the schedule factor.

In summary, the hypothesis regarding improved schedule performance for projects with negative incentives was established.

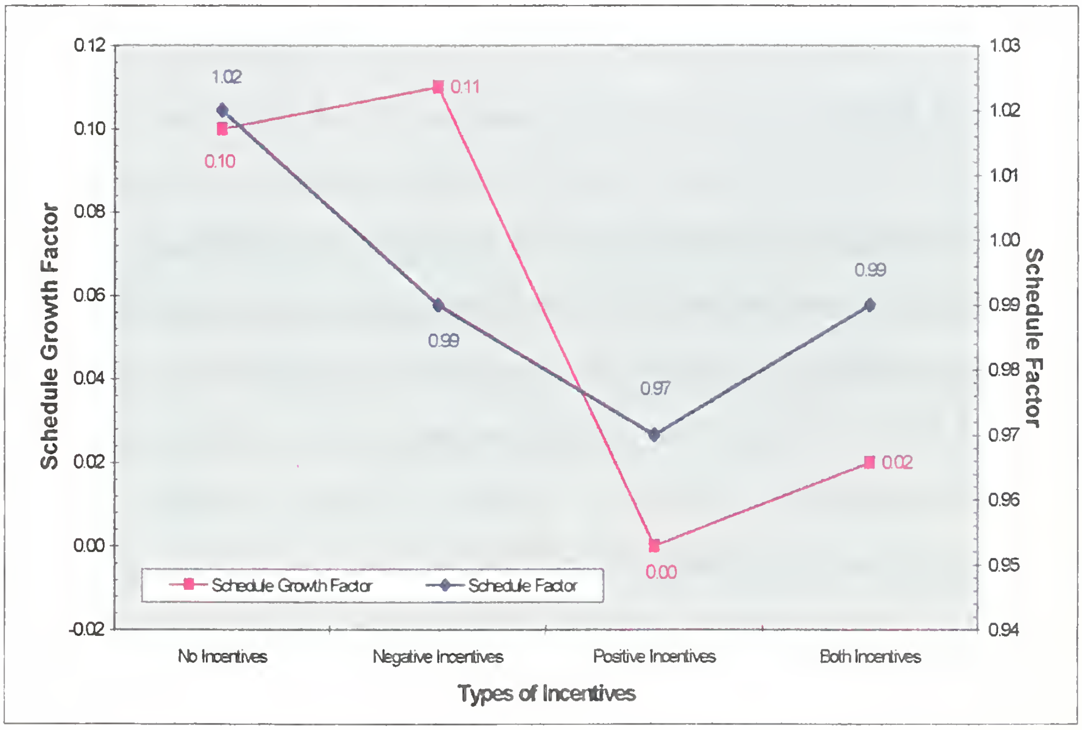

Figure V - 6, Effect of Schedule Incentives on Schedule and Schedule Growth

Moreover, the data established that even better performance was obtained when positive incentives were used and that performance with both positive and negative incentives was less then those with positive incentives, but better then those with negative incentives.

The effect of both positive and negative incentives, although demonstrating improved schedule performance over projects with no incentives, does not show better performance than projects with negative incentives and actually results in decreased performance than projects with positive incentives. Thus, it can not be said that a combination of positive and negative incentives provides the best schedule performance, and the original hypothesis is not proven correct.

An examination of the schedule growth factor trend in Table V - 6 shows that negative cost incentives slightly increased schedule growth by 1% and that positive incentives provided the best schedule growth performance with 0% schedule growth, an improvement of 10% over projects with no incentives. A combination of both positive and negative incentives provided better performance than both negative and no incentive projects, but was lower by 2% than those projects with only positive incentives. As a result, the original hypothesis regarding negative incentives and both positive and negative incentives is shown to be only partially true. The hypothesis regarding positive incentives is proven to be correct.

Most noteworthy, however, are the benefits provided by only positive incentives. A 10% reduction in schedule growth over the life of a construction

project could easily result in an early completion measured in weeks. Hence, positive incentives are shown to be the best option and should be utilized exclusively.

SAFETY INCENTIVES

Table V - 4 shows the calculated factor analysis that was completed for projects with safety incentives. As with the cost and schedule incentive analysis, this table is a summary of all the data collected from both contractors and owners. Like projects with cost incentives, the number of projects with negative safety incentives is limited. The number of projects with both positive and negative incentives is also limited, although there are more projects with this type of incentive than projects with negative incentives. Projects with positive incentives and those projects without safety incentives were amply provided for this analysis and the results should deem to yield a low margin of error.

As with the previous analysis, Table V - 4 includes the summary of the calculated factors, with means, medians, standard deviations and variance. The F-Test analysis that compares each type of incentive to each of the other types is also shown.

The statistical validity of the data used was determined by the use of histograms. Figure V - 7 plots the frequency versus the recordable incident rate for projects with positive, negative, both positive and negative, and projects without safety incentives.

Safety Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner and Contractor Data, First and Second Survey	**Both Positive and Negative Incentives**	N	13	14	12	13	14	14
		Mean	1.02	0.08	0.97	0.04	3.06	0.24
		Median	0.91	0.02	0.90	0.02	1.91	0.00
		Std. Deviation	0.34	0.34	0.28	0.27	3.34	0.38
		Variance	0.12	0.11	0.08	0.07	11.16	0.14
		F-Test v. Without	0.55	0.49	0.13	0.74	0.00	0.00
		F-Test v. Neg.	0.93	0.09	0.68	0.53	0.30	0.00
		F-Test v. Pos	0.01	0.03	0.01	0.52	0.16	0.00
	Positive Incentives	N	56	68	59	70	69	69
		Mean	1.01	0.14	1.01	0.07	4.07	0.56
		Median	1.00	0.05	1.00	0.00	2.38	0.00
		Std. Deviation	0.20	0.59	0.17	0.24	4.75	1.13
		Variance	0.04	0.34	0.03	0.06	22.53	1.28
		F-Test v. Without	0.00	0.00	0.05	0.47	0.00	0.00
		F-Test v. Neg.	0.31	0.03	0.91	0.38	0.68	0.66
	Negative Incentives	N	3	3	2	2	3	3
		Mean	1.18	0.41	1.11	0.42	4.08	1.15
		Median	1.16	0.42	1.11	0.42	2.64	1.05
		Std. Deviation	0.28	0.07	0.13	0.31	4.96	1.20
		Variance	0.08	0.01	0.02	0.10	24.60	1.45
		F-Test v. Without	0.76	0.07	0.90	0.45	0.59	0.38
	Without Incentives	N	204	221	198	216	189	192
		Mean	1.03	0.13	1.00	0.07	5.74	1.10
		Median	0.99	0.06	1.00	0.02	3.36	0.00
		Std. Deviation	0.40	0.40	0.21	0.26	8.42	2.61
		Variance	0.16	0.16	0.05	0.07	70.93	6.82

Table V - 4, Factors Calculated for Projects with Safety Incentives

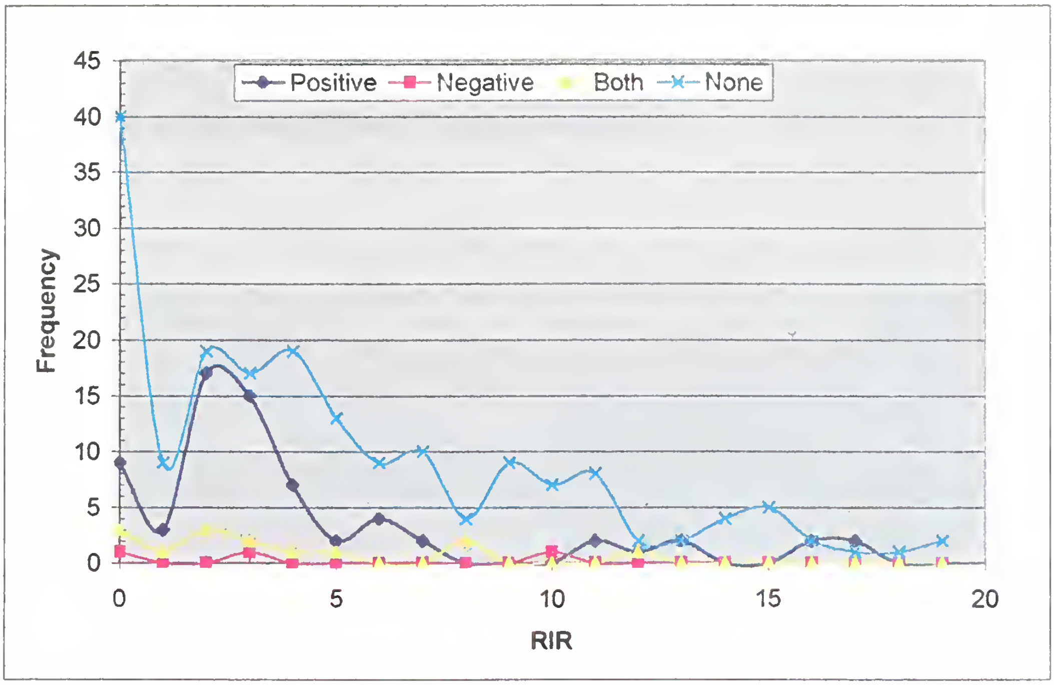

Figure V - 7, Histogram, Effect of Safety Incentives on RIR

As shown in Figure V - 7, the data, while resembling a normal curve, has significant "dips," particularly around the RIR value of 1.0. At this time the meaning of this cannot be contributed to any known factor, but it is believed that as more projects become available to CII, these irregularities will disappear and the data will produce more normal results. Even with these irregularities, it is obvious that the tendency is for projects to have a very low RIR, with many projects approaching a zero RIR. This provides favorable results for the analysis of this data. Figure V - 8 shows the frequency for LWCIR.

Figure V - 8 indicates a very strong tendency for the data to cluster around the value of zero. This is to be expected since the frequency of serious accidents

on projects will normally be very low. Since the data exhibits a consistent curve, the validity of the data obtained is not questionable.

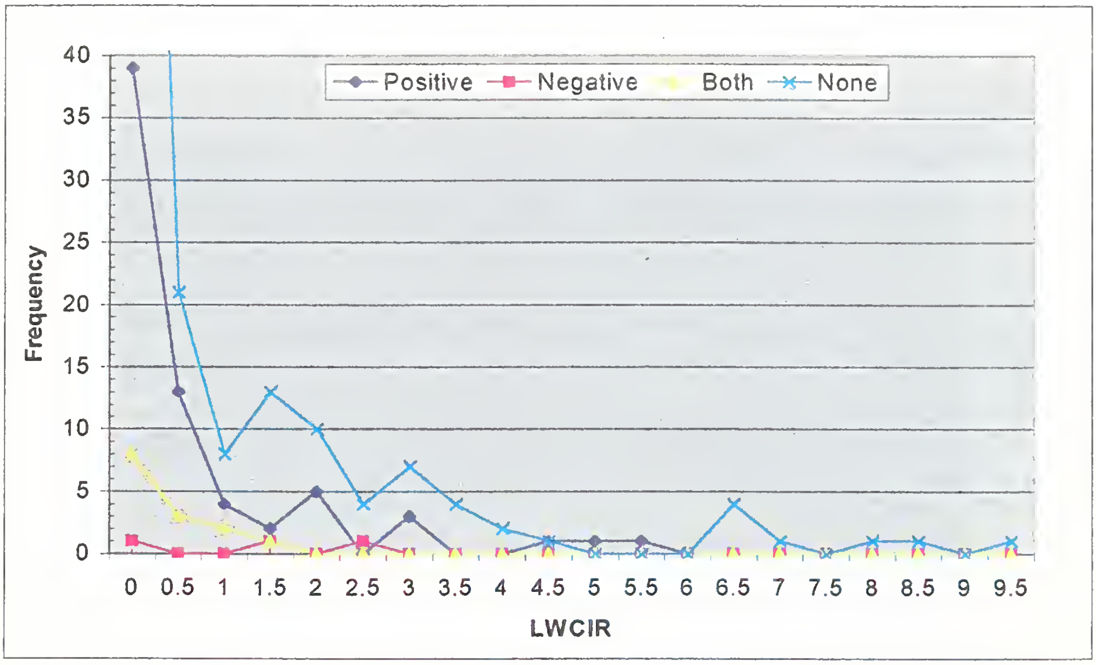

Figure V - 8, Histogram, Effect of Safety Incentives on LWCIR

The second statistical tool that was used to provide an evaluation of the significance difference in the data was the F-test. F-test factors were calculated to determine if the data exhibited significant differences based on the type of incentive. An evaluation of the F-test values as calculated and the critical F-test values shows that none of the calculated values meet the critical value, and thus no significant difference in the data is noted. It is hypothesized that the effects of

safety incentives are probably very small. Furthermore, an F-test would probably not be able to differentiate between contracts with or without safety incentives.

A trend analysis of the effect of safety incentives on RIR and LWCIR is shown in Figure V - 9. The effects of safety incentives on RIR are identical to what was originally expected, with negative incentives providing better performance than projects without incentives, positive incentives being better the negative and no incentives and both positive and negative being the best.

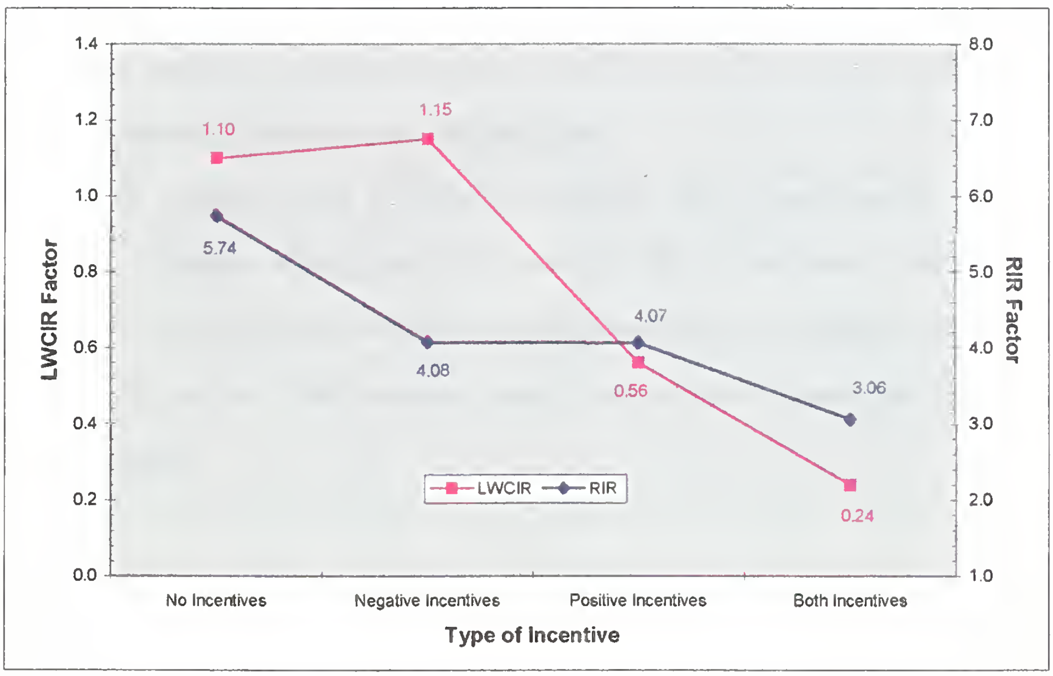

Figure V - 9, Effect of Safety Incentives on RIR and LWCIR

Of significance is the fact that using both negative and positive incentives provided a 78% decrease in the RIR. The use of safety incentives also provided

decreases in the LWCIR. As shown in Figure V - 9, the LWCIR rate was best when both negative and positive incentives were used. Interestingly enough, the trend analysis shows an increase of LWCIR for negative incentives, although it should be noted that there were only three negative incentive projects upon which to base this result. It is highly probable that a larger number of negative safety incentive projects would show that the LWCIR is less for projects with negative incentives versus projects with no incentives.

In summary, the hypothesis regarding safety performance is proven correct. Negative safety incentives are better than no incentives, positive safety incentives are better than negative safety incentives or no safety incentives and that both positive and negative safety incentives provide the best safety performance.

Chapter 6

Conclusions

This study began by asking the question: Are incentives effective? And if so, can the benefits be quantified? And finally, what types of incentives are best? Based on these questions, three hypotheses were developed that guided this study of incentives. These three hypotheses will be examined individually to determine the accuracy of their accuracy.

THE FIRST HYPOTHESIS

"Projects with negative incentives have slightly better cost, schedule, and safety performance than projects with no incentives"

To examine the results of the research on this hypothesis, Table VI - 1 has been constructed from the data presented in Table V - 2, Table V - 3, and Table V - 4. This table shows the effect of negative incentives upon construction projects. As is readily seen, negative incentives hamper, and in some case seriously inhibit the performance of construction contracts in cost, schedule and safety performance. In fact, it is noted that the performance of these negative incentive projects is worse than those contracts that offer no incentives.

However, in defense of negative incentives, it should be stated again that the number of negative incentive projects for both cost and safety were extremely

limited. It is possible that additional data in this area would still show that negative incentives do perform worse than projects with no incentives. It is theorized that the actual quantification of the negative performance would moderate as the amount of data increased.

Consequently, the use of negative incentives for any purpose is not recommended, and the hypothesis as stated is proven incorrect.

	Cost, % Change		**Schedule, % Change**		**Safety, % Change**	
	Budget	***Cost Growth***	***Schedule Factor***	***Schedule Growth***	***RIR***	***LWCIR***
Negative	-6% *	-12% *	3%	-1%	29% **	-5% **
Positive	2%	-2%	5%	10%	29%	49%
Both	3%	-1%	3%	8%	47%	78%

Note: All percentages are relative to projects with no incentives.

* Based on 6 negative cost incentive projects.

** Based on 3 negative safety incentive projects.

Table VI - 1, Summary of the Effects of Incentives on Construction

THE SECOND HYPOTHESIS

"Projects with positive incentives have better cost, schedule and safety performance than projects with no incentives or projects with only negative incentives."

Table VI - 1 shows that positive incentives result in better performance in all area except in the areas of cost growth, where only a minor decrease was noted. In many instances, it appears that owners use cost incentives on projects that are poorly defined. The reasoning being that the owners know that potential for poor cost performance due to a poorly defined scope of work, or an incomplete set of plans may lead to major increases in construction costs. Owners respond to this by introducing cost incentives to mitigate the potential for cost over-runs. This leads to the assumption that the original cost estimates for cost incentive projects are less accurate, and that the budget and cost growth factors would be affected.

Another contributing factor is the fact that cost incentives are only used on cost reimbursable contracts. These types of contracts generally have less defined scopes of work, estimates are less accurate and many of these contracts are fast-track projects. All of these factors produce results such as those obtained in this study. Thus, it is believed that cost incentives are effective, although this is not supported by the data.

In summary, positive incentives have been shown to result in better performance than projects with negative incentives or projects with no incentives. Thus the hypothesis as proposed is proven to be accurate.

THE THIRD HYPOTHESIS

"Projects with both positive and negative incentives have much better cost, schedule and safety performance than projects with no incentives or projects with only positive or negative incentives."

This hypothesis was formulated on the assumption that both positive and negative incentives would provide a benefit to the project. As has been shown, negative incentives actually inhibit the project. So what happens when negative and positive incentives are combined? As Table VI - 1 illustrates; the results obtained were mixed. In one case, the use of both positive and negative incentives was extremely effective for safety performance. In the areas of cost and schedule performance, the results showed that negative incentives inhibited the performance or provided little benefit. The use of both types of incentives results in better performance then negative incentives or projects with no incentives. However, in most cases positive incentives performed as well as or better then the use of both negative and positive incentives. Therefore, there is no justification for the use of both positive and negative incentives in the area of cost or schedule performance. In fact, the additional administrative resources required to administer both of these incentives make this type of incentive impractical.

In summary, the third hypothesis yields mixed results, with the use of both positive and negative incentives extremely effective for safety performance, but not recommended for cost or schedule performance. Hence, the original hypothesis is only applicable to the use of safety incentives. Use of both positive and negative incentives for cost and schedule performance should be carefully considered before application.

Appendix A: Analysis of Data by Owner or Contractor, and by First or Second Survey for Factors

Cost Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner Data, First Survey	*Both Positive and Negative Incentives*	N	4	4	4	4	2	2
		Mean	0.97	-0.01	1.05	0.00	3.32	0.60
		Median	0.99	0.00	1.07	0.03	3.32	0.60
		Std. Deviation	0.08	0.06	0.24	0.19	0.85	0.68
		Variance	0.01	0.00	0.06	0.04	0.72	0.47
		F-Test v. Without	0.03	0.01	0.97	0.63	0.26	0.35
		F-Test v. Neg.	-	-	-	-	-	-
		F-Test v. Pos	0.23	0.08	0.14	0.38	0.30	0.42
	Positive Incentives	N	10	10	10	10	16	16
		Mean	0.96	0.00	1.02	0.03	4.43	1.09
		Median	0.94	0.00	0.99	-0.01	2.41	0.04
		Std. Deviation	0.18	0.19	0.13	0.14	4.45	2.50
		Variance	0.03	0.04	0.02	0.02	19.77	6.26
		F-Test v. Without	0.02	0.03	0.03	0.03	0.53	0.37
		F-Test v. Neg.	-	-	-	-	-	-
	Negative Incentives	N	0	0	0	0	0	0
		Mean	-	-	-	-	-	-
		Median	-	-	-	-	-	-
		Std. Deviation	-	-	-	-	-	-
		Variance	-	-	-	-	-	-
		F-Test v. Without	-	-	-	-	-	-
	Without Incentives	N	67	67	63	63	62	62
		Mean	0.98	0.06	1.03	0.09	4.54	0.98
		Median	0.95	0.01	1.00	0.06	3.25	0.00
		Std. Deviation	0.37	0.38	0.26	0.27	5.17	3.09
		Variance	0.14	0.15	0.07	0.07	26.68	9.56

Cost Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner Data, Second Survey	***Both Positive and Negative Incentives***	**N**	6	6	6	7	6	6
		Mean	1.10	0.12	1.14	0.14	3.51	0.26
		Median	0.92	-0.02	1.02	0.11	1.23	0.00
		Std. Deviation	0.50	0.50	0.41	0.37	4.66	0.41
		Variance	0.25	0.25	0.17	0.14	21.72	0.17
		F-Test v. Without	0.00	0.01	0.03	0.40	0.86	0.06
		F-Test v. Neg.	-	-	-	-	-	-
		F-Test v. Pos	0.08	0.06	0.05	0.08	0.28	0.00
	Positive Incentives	**N**	11	11	8	12	12	11
		Mean	1.03	0.08	0.98	-0.03	3.72	0.81
		Median	1.00	0.05	0.99	0.00	2.54	0.00
		Std. Deviation	0.26	0.25	0.18	0.21	3.22	2.02
		Variance	0.07	0.06	0.03	0.04	10.35	4.10
		F-Test v. Without	0.60	0.83	0.50	0.16	0.19	0.00
		F-Test v. Neg.	-	-	-	-	-	-
	Negative Incentives	**N**	1	1	0	0	0	0
		Mean	1.36	0.36	-	-	-	-
		Median	1.36	0.36	-	-	-	-
		Std. Deviation	-	-	-	-	-	-
		Variance	-	-	-	-	-	-
		F-Test v. Without	-	-	-	-	-	-
	Without Incentives	**N**	49	48	34	48	36	32
		Mean	1.02	0.06	1.06	0.15	2.97	0.42
		Median	0.97	0.03	1.00	0.05	0.40	0.00
		Std. Deviation	0.24	0.24	0.23	0.31	4.66	0.99
		Variance	0.06	0.06	0.05	0.09	21.72	0.98

Cost Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Contractor Data, First Survey	*Both Positive and Negative Incentives*	N	13	13	12	12	14	14
		Mean	0.99	0.20	0.99	0.09	6.27	1.03
		Median	1.00	0.03	1.00	0.05	5.67	0.30
		Std. Deviation	0.09	0.48	0.13	0.15	4.89	1.42
		Variance	0.01	0.23	0.02	0.02	23.88	2.02
		F-Test v. Without	0.00	0.90	0.73	0.13	0.00	0.03
		F-Test v. Neg.	0.02	0.11	0.17	0.97	0.87	0.99
		F-Test v. Pos	0.08	0.02	0.03	0.07	0.00	0.01
	Positive Incentives	N	23	23	24	24	22	22
		Mean	1.04	0.30	1.00	0.03	7.07	1.14
		Median	1.00	0.10	0.97	-0.03	1.93	0.00
		Std. Deviation	0.14	0.93	0.25	0.27	13.37	2.98
		Variance	0.02	0.87	0.06	0.07	178.76	8.91
		F-Test v. Without	0.17	0.03	0.67	0.64	0.15	0.30
		F-Test v. Neg.	0.17	0.03	0.67	0.64	0.15	0.30
	Negative Incentives	N	3	3	2	2	3	3
		Mean	1.21	0.35	1.03	0.12	6.94	1.15
		Median	1.16	0.33	1.03	0.12	8.58	1.05
		Std. Deviation	0.24	0.12	0.24	0.11	3.76	1.20
		Variance	0.06	0.01	0.06	0.01	14.14	1.45
		F-Test v. Without	0.32	0.10	0.19	0.73	0.24	0.41
	Without Incentives	N	66	66	64	64	62	62
		Mean	1.11	0.24	0.97	0.07	7.48	1.55
		Median	1.00	0.13	0.99	0.03	5.46	0.28
		Std. Deviation	0.58	0.51	0.14	0.23	10.43	2.49
		Variance	0.33	0.26	0.02	0.05	108.76	6.21

Cost Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Contractor Data, Second Survey	***Both Positive and Negative Incentives***	**N**	2	2	2	2	2	2
		Mean	0.94	0.06	1.05	0.12	8.17	0.45
		Median	0.94	0.06	1.05	0.12	8.17	0.45
		Std. Deviation	0.08	0.15	0.01	0.11	2.34	0.63
		Variance	0.01	0.02	0.00	0.01	5.46	0.40
		F-Test v. Without	0.57	0.73	0.12	0.92	0.81	0.61
		F-Test v. Neg.	0.58	0.34	0.43	0.29	0.88	0.50
		F-Test v. Pos	0.38	0.77	0.18	0.56	0.64	0.42
	Positive Incentives	**N**	9	15	8	15	14	14
		Mean	1.02	0.05	0.95	0.08	3.74	0.29
		Median	1.03	0.04	0.97	0.00	2.17	0.00
		Std. Deviation	0.06	0.16	0.10	0.30	5.57	0.48
		Variance	0.00	0.03	0.01	0.09	30.98	0.23
		F-Test v. Without	0.00	0.01	0.22	0.01	0.27	0.36
		F-Test v. Neg.	0.04	0.01	0.49	0.28	0.76	0.81
	Negative Incentives	**N**	2	2	2	2	2	2
		Mean	0.79	0.05	0.99	0.31	2.00	0.19
		Median	0.79	0.05	0.99	0.31	2.00	0.19
		Std. Deviation	0.17	0.53	0.03	0.47	2.83	0.26
		Variance	0.03	0.28	0.00	0.22	8.02	0.07
		F-Test v. Without	0.92	0.19	0.33	0.02	0.96	0.66
	Without Incentives	**N**	31	35	32	36	28	32
		Mean	1.03	0.13	0.95	0.00	2.86	0.27
		Median	1.00	0.07	0.96	-0.01	1.05	0.00
		Std. Deviation	0.23	0.31	0.16	0.18	4.36	0.61
		Variance	0.05	0.09	0.02	0.03	18.99	0.37

Schedule Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner Data, First Survey	***Both Positive and Negative Incentives***	**N**	7	7	7	7	7	7
		Mean	0.89	-0.08	0.98	-0.03	7.31	3.46
		Median	0.86	-0.09	0.91	-0.09	3.92	0.00
		Std. Deviation	0.09	0.08	0.22	0.20	7.02	8.63
		Variance	0.01	0.01	0.05	0.04	49.32	74.51
		F-Test v. Without	0.00	0.00	0.79	0.63	0.10	0.00
		F-Test v. Neg.	0.29	0.83	0.42	0.28	0.07	0.02
		F-Test v. Pos	0.10	0.03	0.71	0.97	0.35	0.00
	Positive Incentives	**N**	10	10	10	10	15	14
		Mean	0.96	0.00	1.03	0.07	4.74	0.45
		Median	0.95	-0.02	1.00	0.05	2.44	0.00
		Std. Deviation	0.19	0.20	0.20	0.21	5.26	1.00
		Variance	0.03	0.04	0.04	0.04	27.66	1.00
		F-Test v. Without	0.02	0.03	0.41	0.59	0.50	0.39
		F-Test v. Neg.	0.01	0.05	0.22	0.24	0.23	0.00
	Negative Incentives	**N**	7	7	5	5	8	8
		Mean	0.96	0.05	1.14	0.32	2.14	2.05
		Median	0.96	0.03	0.98	0.26	0.73	0.73
		Std. Deviation	0.06	0.09	0.31	0.33	3.35	3.34
		Variance	0.00	0.01	0.10	0.11	11.21	11.13
		F-Test v. Without	0.00	0.00	0.41	0.31	0.37	0.00
	Without Incentives	**N**	58	58	56	56	51	51
		Mean	0.99	0.06	1.02	0.07	4.45	0.63
		Median	0.94	0.01	1.00	0.04	3.70	0.00
		Std. Deviation	0.39	0.41	0.25	0.25	4.63	1.25
		Variance	0.16	0.17	0.06	0.06	21.46	1.55

Schedule Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner Data, Second Survey	***Both Positive and Negative Incentives***	**N**	4	6	5	7	6	6
		Mean	1.23	0.31	1.19	0.20	3.93	0.30
		Median	0.95	0.02	1.12	0.20	1.70	0.12
		Std. Deviation	0.59	0.51	0.44	0.36	4.35	0.39
		Variance	0.35	0.26	0.19	0.13	18.93	0.15
		F-Test v. Without	0.00	0.00	0.03	0.81	0.00	0.41
		F-Test v. Neg.	0.00	0.00	0.08	0.94	0.00	0.45
		F-Test v. Pos	0.00	0.00	0.33	0.62	0.00	0.64
	Positive Incentives	**N**	8	12	9	13	13	12
		Mean	0.93	0.04	0.97	-0.03	4.11	1.15
		Median	0.91	0.02	0.98	-0.04	2.13	0.00
		Std. Deviation	0.14	0.20	0.18	0.20	4.00	2.26
		Variance	0.02	0.04	0.03	0.04	16.00	5.10
		F-Test v. Without	0.99	0.57	0.51	0.05	0.00	0.00
		F-Test v. Neg.	-	0.43	-	-	-	-
	Negative Incentives	**N**	1	2	1	1	1	1
		Mean	0.89	0.18	1.01	0.15	0.00	0.00
		Median	0.89	0.18	1.01	0.15	0.00	0.00
		Std. Deviation	-	0.26	-	-	-	-
		Variance	-	0.07	-	-	-	-
		F-Test v. Without	-	0.54	-	-	-	-
	Without Incentives	**N**	33	48	31	48	32	31
		Mean	0.95	0.04	1.06	0.11	-4.05	0.27
		Median	0.96	0.02	1.00	0.01	0.40	0.00
		Std. Deviation	0.15	0.23	0.23	0.35	40.62	0.57
		Variance	0.02	0.05	0.05	0.12	1649.77	0.33

Schedule Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Contractor Data, First Survey	*Both Positive and Negative Incentives*	N	23	23	20	21	24	24
		Mean	1.02	0.11	0.94	-0.02	5.71	0.74
		Median	1.00	0.04	0.95	-0.03	4.48	0.21
		Std. Deviation	0.13	0.20	0.13	0.14	4.33	1.13
		Variance	0.02	0.04	0.02	0.02	18.73	1.28
		F-Test v. Without	0.00	0.00	0.02	0.00	0.00	0.00
		F-Test v. Neg.	0.00	0.00	0.57	0.45	0.31	0.00
		F-Test v. Pos	0.00	0.00	0.16	0.83	0.91	0.00
	Positive Incentives	N	23	22	24	24	21	21
		Mean	0.98	0.30	0.94	-0.02	3.31	0.77
		Median	1.00	0.10	0.95	-0.03	1.94	0.00
		Std. Deviation	0.26	0.95	0.10	0.14	4.21	2.34
		Variance	0.07	0.90	0.01	0.02	17.76	5.50
		F-Test v. Without	0.00	0.05	0.00	0.00	0.00	0.48
		F-Test v. Neg.	0.00	0.00	0.43	0.57	0.28	0.34
	Negative Incentives	N	19	19	19	19	18	18
		Mean	1.06	0.13	0.94	0.01	7.81	2.47
		Median	1.06	0.13	0.98	0.06	6.35	1.56
		Std. Deviation	0.06	0.08	0.12	0.16	5.43	2.92
		Variance	0.00	0.01	0.01	0.03	29.43	8.55
		F-Test v. Without	0.00	0.00	0.00	0.01	0.00	0.69
	Without Incentives	N	40	41	37	38	38	38
		Mean	1.15	0.37	1.05	0.19	10.01	1.60
		Median	1.00	0.22	1.00	0.09	5.52	0.00
		Std. Deviation	0.74	0.66	0.23	0.29	15.40	2.72
		Variance	0.54	0.44	0.05	0.08	237.30	7.42

Schedule Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Contractor Data, Second Survey	*Both Positive and Negative Incentives*	**N**	2	2	2	2	2	2
		Mean	1.28	0.37	1.00	0.00	1.32	0.00
		Median	1.28	0.37	1.00	0.00	1.32	0.00
		Std. Deviation	0.36	0.38	0.09	0.10	0.31	0.00
		Variance	0.13	0.14	0.01	0.01	0.10	0.00
		F-Test v. Without	0.43	0.37	0.91	0.82	0.11	-
		F-Test v. Neg.	0.11	0.57	0.69	0.32	0.06	-
		F-Test v. Pos	0.04	0.08	0.93	0.94	0.31	-
	Positive Incentives	**N**	4	11	5	11	10	11
		Mean	1.01	0.01	0.96	0.01	2.04	0.12
		Median	1.02	0.00	0.99	0.03	2.01	0.00
		Std. Deviation	0.07	0.16	0.12	0.15	1.57	0.19
		Variance	0.01	0.02	0.01	0.02	2.46	0.04
		F-Test v. Without	0.05	0.06	0.64	0.28	0.00	0.00
		F-Test v. Neg.	0.26	0.03	0.56	0.00	0.00	0.00
	Negative Incentives	**N**	8	9	7	9	7	7
		Mean	0.94	0.13	0.99	0.21	5.39	0.43
		Median	0.99	0.13	1.02	0.27	3.70	0.21
		Std. Deviation	0.16	0.33	0.09	0.48	7.61	0.60
		Variance	0.02	0.11	0.01	0.23	57.84	0.36
		F-Test v. Without	0.11	0.47	0.19	0.00	0.06	1.00
	Without Incentives	**N**	31	33	31	34	28	31
		Mean	0.99	0.11	0.95	0.00	3.44	0.31
		Median	1.00	0.07	0.97	0.00	1.88	0.00
		Std. Deviation	0.28	0.28	0.16	0.12	4.57	0.63
		Variance	0.08	0.08	0.02	0.01	20.91	0.40

Safety Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner Data, First Survey	***Both Positive and Negative Incentives***	**N**	1	1	1	1	1	1
		Mean	0.86	0.03	0.75	-0.25	2.72	1.09
		Median	0.86	0.03	0.75	-0.25	2.72	1.09
		Std. Deviation	-	-	-	-	-	-
		Variance	-	-	-	-	-	-
		F-Test v. Without	-	-	-	-	-	-
		F-Test v. Neg.	-	-	-	-	-	-
		F-Test v. Pos	-	-	-	-	-	-
	Positive Incentives	**N**	74	74	69	69	73	72
		Mean	0.96	0.02	1.02	0.08	4.77	1.05
		Median	0.93	0.00	0.99	0.06	3.33	0.00
		Std. Deviation	0.34	0.34	0.26	0.26	5.10	3.06
		Variance	0.12	0.11	0.07	0.07	26.01	9.37
		F-Test v. Without	0.44	0.25	0.87	0.87	0.60	0.32
		F-Test v. Neg.	-	-	-	-	-	-
	Negative Incentives	**N**	0	0	0	0	0	0
		Mean	-	-	-	-	-	-
		Median	-	-	-	-	-	-
		Std. Deviation	-	-	-	-	-	-
		Variance	-	-	-	-	-	-
		F-Test v. Without	-	-	-	-	-	-
	Without Incentives	**N**	59	59	55	55	56	55
		Mean	0.98	0.06	1.02	0.08	4.82	1.22
		Median	0.95	0.00	0.99	0.04	3.25	0.00
		Std. Deviation	0.38	0.39	0.26	0.27	5.44	3.47
		Variance	0.14	0.15	0.07	0.07	29.60	12.01

Safety Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Owner Data, Second Survey	*Both Positive and Negative Incentives*	**N**	5	6	5	6	6	6
		Mean	1.12	0.12	1.07	0.08	3.51	0.26
		Median	0.91	-0.02	0.89	0.00	1.23	0.00
		Std. Deviation	0.56	0.50	0.42	0.37	4.66	0.41
		Variance	0.32	0.25	0.17	0.14	21.72	0.17
		F-Test v. Without	0.00	0.00	0.04	0.39	0.80	0.02
		F-Test v. Neg.	-	-	-	-	-	-
		F-Test v. Pos	0.19	0.10	0.21	0.59	0.75	0.01
	Positive Incentives	**N**	8	13	9	14	13	12
		Mean	1.07	0.14	1.01	0.12	4.74	0.87
		Median	1.00	0.10	0.98	0.02	2.75	0.28
		Std. Deviation	0.32	0.28	0.25	0.32	4.30	1.42
		Variance	0.11	0.08	0.06	0.10	18.51	2.03
		F-Test v. Without	0.00	0.40	0.64	0.74	0.90	0.68
		F-Test v. Neg.	-	-	-	-	-	-
	Negative Incentives	**N**	0	0	0	0	0	0
		Mean	-	-	-	-	-	-
		Median	-	-	-	-	-	-
		Std. Deviation	-	-	-	-	-	-
		Variance	-	-	-	-	-	-
		F-Test v. Without	-	-	-	-	-	-
	Without Incentives	**N**	32	45	32	45	29	29
		Mean	0.94	0.05	1.06	0.12	3.07	0.41
		Median	0.95	0.03	1.00	0.02	0.80	0.00
		Std. Deviation	0.14	0.24	0.23	0.30	4.51	1.31
		Variance	0.02	0.06	0.05	0.09	20.37	1.71

Safety Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Contractor Data, First Survey	***Both Positive and Negative Incentives***	**N**	7	7	6	6	7	7
		Mean	0.97	0.04	0.92	0.05	2.72	0.10
		Median	1.01	0.02	0.92	0.02	2.14	0.00
		Std. Deviation	0.11	0.19	0.12	0.12	2.39	0.14
		Variance	0.01	0.04	0.01	0.01	5.73	0.02
		F-Test v. Without	0.00	0.02	0.27	0.09	0.00	0.00
		F-Test v. Neg.	0.16	0.79	-	-	0.17	0.00
		F-Test v. Pos	0.51	0.00	0.22	0.96	0.04	0.00
	Positive Incentives	**N**	21	21	22	22	21	21
		Mean	1.02	0.36	0.96	0.01	3.93	0.66
		Median	1.00	0.11	0.96	0.00	1.77	0.00
		Std. Deviation	0.14	0.97	0.08	0.13	5.60	1.41
		Variance	0.02	0.95	0.01	0.02	31.36	2.00
		F-Test v. Without	0.00	0.00	0.00	0.00	0.00	0.00
		F-Test v. Neg.	0.26	0.17	-	-	0.78	0.98
	Negative Incentives	**N**	2	2	1	1	2	2
		Mean	1.32	0.40	1.20	0.20	6.12	1.73
		Median	1.32	0.40	1.20	0.20	6.12	1.73
		Std. Deviation	0.23	0.10	-	-	4.92	0.95
		Variance	0.05	0.01	-	-	24.25	0.91
		F-Test v. Without	0.64	0.32	-	-	0.65	0.54
	Without Incentives	**N**	75	75	73	73	69	70
		Mean	1.10	0.24	1.00	0.08	8.89	1.73
		Median	1.00	0.12	1.00	0.04	6.33	0.37
		Std. Deviation	0.54	0.51	0.19	0.26	11.75	2.76
		Variance	0.29	0.26	0.04	0.07	138.08	7.62

Safety Incentives, Construction Phase			Budget Factor	Cost Growth	Schedule Factor	Schedule Growth	RIR	LWCIR
Contractor Data, Second Survey	*Both Positive and Negative Incentives*	**N**	0	0	0	0	0	0
		Mean	-	-	-	-	-	-
		Median	-	-	-	-	-	-
		Std. Deviation	-	-	-	-	-	-
		Variance	-	-	-	-	-	-
		F-Test v. Without	-	-	-	-	-	-
		F-Test v. Neg.	-	-	-	-	-	-
		F-Test v. Pos	-	-	-	-	-	-
	Positive Incentives	**N**	5	12	6	12	11	12
		Mean	1.00	0.03	0.95	0.09	3.89	0.32
		Median	1.06	0.01	0.97	0.02	2.45	0.00
		Std. Deviation	0.10	0.17	0.11	0.34	6.21	0.52
		Variance	0.01	0.03	0.01	0.12	38.51	0.27
		F-Test v. Without	0.15	0.06	0.48	0.00	0.08	0.78
		F-Test v. Neg.	-	-	-	-	-	-
	Negative Incentives	**N**	1	1	1	1	1	1
		Mean	0.92	0.42	1.02	0.64	0.00	0.00
		Median	0.92	0.42	1.02	0.64	0.00	0.00
		Std. Deviation	-	-	-	-	-	-
		Variance	-	-	-	-	-	-
		F-Test v. Without	-	-	-	-	-	-
	Without Incentives	**N**	38	42	38	43	35	38
		Mean	1.02	0.12	0.96	0.01	3.23	0.27
		Median	1.00	0.08	0.97	0.00	1.95	0.00
		Std. Deviation	0.22	0.29	0.15	0.17	4.15	0.57
		Variance	0.05	0.08	0.02	0.03	17.21	0.32

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Vita

James David Oliver was born in 1963 to James Donald and Sharon Janette Oliver. The oldest of three children, he attended Vernon High School and graduated in 1981. He then attended Vernon Regional Junior College where he obtained his Associate Degree in Drafting and Design in 1984. After attending Texas Tech University for three years, he graduated with a Bachelors Degree in Mechanical Engineering. The author then spent two years as a project engineer with the Texas Department of Highways and Public Transportation where he worked in materials testing, drafting, and quality assurance for construction projects. He then joined the United States Navy as a Civil Engineer Corp officer and was commissioned as an Ensign in 1988. After a three year public works tour at the Naval Station Pearl Harbor, Hawaii, he then was assigned in 1991 as a Contracting Officer for construction at the Camp Pendleton Marine Corp Base in Oceanside, California. In 1993 he was transferred for a one-year tour as the Service Contract Manager for the Naval Base on Diego Garcia. This was followed by a two-year tour as a Company Commander and Detachment Officer in Charge with Naval Mobile Construction Battalion FOUR.

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